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Popular Mechanics

HOW YOUR WORLD WORKS

ANNOUNCING
AMERICA'S
MOST POPULAR
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THE CONTEST!
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EXCLUSIVE

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*AND THE MAN WHO
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*HOW THEY'RE TRYING
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DOING ON OUR COVER?

(WHAT, YOU'RE COMPLAINING?)

Presenting Our
First Annual Awards
for the

**GREATEST
MOVIE EFFECTS
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PLUS

**THE NEW MUSTANG
IS THE BEST EVER**
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by Ezra Dyer **PAGE 26**





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Don't work for the man. Become him—at one of the 14 best cities in the U.S. for small businesses, makers, and idealist brewers.

THE BEST STARTUP CITIES

Originally from Milwaukee, David Bauer chose Asheville, North Carolina, as the place to start Farm & Sparrow, his artisanal bakery that mills its own flour from heirloom grains.

PHOTOGRAPH BY JOHNNY AUTRY



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ON THE COVER:

Olivia Munn photograph by Art Streiber. Set and props by Walter Barnett; wardrobe styling by Jill Roth; hair by Maranda/The Wall Group; makeup by Shane Paish/Walter Schupfer Management; manicure by Emi Kudo/Opus Beauty; black top by Ina Soltani; gold jeans by J Brand; earrings by Jacquie Aiche; bracelet by Anita Ko

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PREAMBLE

LETTERS

FACEBOOK MAY HAVE ITS DANGERS, BUT THE QUIZZES ARE FUN

When I finished reading Bill Gifford's article ("The Benevolent Overlord," November) I put the magazine down and couldn't look at it for a week. Despite its many advantages, Internet technology has become more threatening to individual rights every day. Facebook, I'm sure, has been an unwitting vehicle to suicide, homicide, and personal, financial, and professional ruin. Internet figureheads, or their worshippers and emulators, may see themselves as visionary, innovative, and ambitious, when they may instead lack the necessary insight, wisdom, or morality to be so.

MARK HAWLEY
Seattle



Built for HemisFair '68, the Hilton Palacio del Rio, at 21 stories tall and completed in 202 working days, was a feat of modular construction.

← ACKNOWLEDGING A PREDECESSOR

Before you become so impressed with the Brooklyn building that you cited in your Breakthrough Awards ("The Prefab High-Rise," November), I recommend you learn about one of the first modular high-rise buildings in the U.S., the Hilton Palacio del Rio in San Antonio. I recall watching that truly unique structure being built in 1968. The modular rooms, when raised and put into place, were complete down to having boxes of Kleenex on the night tables.

HUGH K. HIGGINS JR.
Austin, Texas

WRITE TO US

Letters to the editor can be emailed to editor@popularmechanics.com. Include your full name and address. Letters may be edited for length and clarity.

Subscribe: subscribe.popularmechanics.com, 800-333-4948.

OTHER SURPRISING CELEBRITIES TO GRACE OUR COVER

In honor of this month's cover star, Olivia Munn.



Jimmy Carter
August 1984



George Plimpton
April 1986



Bruce Willis
November 1987



Tim Allen
April 1993

THE COGENT LIBERTARIAN'S GUIDE TO CONGRESSIONALLY SUPPORTED INNOVATION

Your "Congressional Scorecard" (November) is not a measure of innovation. It is a measure of corporate welfare. The problem with equating federal spending with levels of innovation is that it assumes innovation won't happen unless the government funds it. This is not the case. Much of the private funding for important research fails to materialize simply because taxes and regulation drain the productive sector of the capital it could otherwise have spent on projects deemed important by market forces.

FRITZ GROSZKRUGER
Dumont, Iowa

Measuring the productivity of congressmen based on the number of laws they've passed is like grading your mechanic by how many repairs he's done for you. More does not necessarily mean better. I'd argue that it usually means worse.

RANDY KAUFMANN
Lenexa, Kan.

IN PRAISE OF THE WING VENT

Doing away with the front quarter-window (Cars, November) has to be one of the biggest errors ever made in Detroit. My '77 Fairmont was the last car I owned that had one. Cracking that little wing vent was usually all that was needed to cool the interior, defog the windows, or extract cigarette smoke. I especially liked the ones that could be opened almost 150 degrees so that the wind blew right on you. Please, Detroit, be realistic and bring back the wing vent.

KEVIN PYLE
Wilmington, Ohio

There was nothing better than pulling the knob that opened a front quarter-window to the outside and providing fresh air to just the driver. The current vent system flows outside air through the engine compartment, warming it, and the dual temperature systems don't work as well as intended. There were times with a wing vent that I got a shot of cold air in a car that was suitably warm for my wife in the passenger seat.

BARRY ULRICH
Ozark, Mo.

OKAY. SAME QUESTION, BUT FOR POOL COVERS.

A friend and I recently completed your qualifying quiz ("Are You Handy?" November), and we both reached the same conclusion: As native Southerners, the snowblower question, No. 17, should be thrown out. Neither of us has ever seen a snowblower, much less used one.

—
JOHN HOERNER
Birmingham, Ala.

WHO SAYS YOU CAN'T BE BOTH A HANDYMAN AND A ROCKET SCIENTIST? AND WELL-READ?

In the November issue of Popular Mechanics, I failed. It was the final exam for a course I never took ("Are You Handy?"). Being a 14-year-old, I know what pliers are, but tongue-and-groove pliers? I'm part of a generation that's taught to be revolutionary engineers, not the guys who take care of things at home. For example, Jem from *To Kill a Mockingbird* read Popular Mechanics, but I bet he didn't breeze over the Skills section like some science geek. This issue taught me that if I'm not going to be the contractor in a world of programmers, I should at least invite the contractor over for some pizza.

—
TERRY CHENG
Fremont, Calif.

CASE IN POINT.

I had difficulty reading growing up, but every chance I got I would go to the library to read Popular Mechanics. Because of the magazine, I became a good reader, went on to graduate with a science degree, and have been teaching for 42 years. Thanks for helping to make me a lifelong learner.

—
ROBERT CHEESEMAN
Shelton, Wash.

WE'RE ALL CHANGING OUR PASSWORDS

The story about Alex Holden on page 86—he's the cybersecurity specialist who uncovered the theft of millions of email addresses and their passwords by Russian hackers last summer, who granted us unprecedented access to his company—got us worried. So we sent him a few of our own email addresses to see if any had been hacked.

NUMBER OF EMAIL ADDRESSES
SENT TO HOLDEN BY POPULAR MECHANICS
STAFFERS:

TEN

NUMBER OF THOSE ADDRESSES
FOR WHICH HOLDEN
FOUND STOLEN PASSWORDS: **FOUR**

MOST EMBARRASSING PASSWORD
UNCOVERED IN HOLDEN'S RECORDS:

"hotnuts"

100 PERCENTAGE OF STAFFERS WHO
CHANGED THEIR PASSWORDS AFTER
HEARING BACK FROM HOLDEN

MOST TROUBLING DISCOVERY:
ONE EDITOR'S EMAIL ADDRESS LED HOLDEN
TO EVERY ONE OF THE EDITOR'S FIVE
PERSONAL AND PROFESSIONAL EMAIL
ACCOUNTS—ADDRESSES AND PASSWORDS—
ALL OF WHICH HAD BEEN HACKED.



THE HANDY QUIZ: AN ANSWER, EXPLAINED
Some of you were wondering what you're supposed to use a spud wrench for (question No. 2 of "Are You Handy?" November). It's mainly used as an ironworker's tool, with a large wrench on one end and a drift pin on the other that is used for aligning bolt holes.

READER PROJECT OF THE MONTH

Currently occupying the position of Handiest Popular Mechanics Reader is John Schmalshof of Dahlonoga, Georgia. The former John Deere technician got his start tinkering when he bought a 1946 Ford at age 14 for \$16. He fixed it up during the two years before he got his driver's license. For his latest project, Schmalshof, now 69, hand-welded this camp chimney at his shop at the golf course where he works as head equipment manager. Made from a single sheet of 4 x 8-foot steel, the stove is 64 inches tall and will be used at the campsite Schmalshof keeps for weekend getaways with his wife. Anyone who thinks he can usurp Schmalshof's vaunted position can send photos and stories of their projects to us at editor@popularmechanics.com.



PREAMBLE



SIX DINNERS

Last night I had dinner with 35 Popular Mechanics readers here in New York. There was Scotch whisky, shrimp cocktail, impassioned discourse about the history and future of Popular Mechanics, and—because we were at Keens, the old steakhouse on 36th Street—there was mutton.

A little context: A few months ago, someone had the idea that we should have a few dinners with readers. Not like those focus groups in sterile rooms with one-way mirrors. These would be informal and fun. We wanted to know what readers like, what they skim past, what they do on weekends, their hopes and dreams. Why? So we can make the magazine better. For them. For you.

So we had these dinners, and they were fantastic. In Boston the room was so loud with conversation you could barely hear yourself talk—always a good sign. In Philadelphia a woman who brings technology into public-school classrooms bonded with a man who rebuilds classic motorcycles. In Baltimore chef Spike Gjerde's hyperlocal food wowed the attendees, who included a 14-year-old and his parents, an Australian diplomat, and the chief caretaker of the city's historic ships. (See page 68 for more on Spike.) In Detroit everybody was upbeat and almost everybody worked for a car company. And in New York, at my table we talked about solar panels, forensic evidence, pneumatic nail guns, mainframe computers, how to get a crane on top of a building, changing your own oil, and home brewing—and that was before dessert.

In city after city, people stayed and talked (and ate and drank) until deep into night. Every event was a blast. They were also hugely valuable. They confirmed that our readers are engaged, informed, curious, opinionated, and damn good company. We walked away with tons of story ideas. Like maybe we should devote more coverage to renewable energy. And we'll try to make sure our tool-usage instruction is not prejudiced against lefties (thank you, Larry in Baltimore). And we will remember, every month, that we're lucky to have you as a reader.

I hope to do more of these this year. If you're invited, come.

Oh, the sixth meal: That was at wd-50, a restaurant owned by one of our contributing editors, the great Wylie Dufresne. In November wd-50 closed after 11 years—the rent went up, which is a joke, because Wylie made the neighborhood desirable in the first place. His cooking is a transformative force because he creates original eating experiences that are shocking to the eye, challenging to the brain, funny, artistic, and (important part) delicious. Toward the end executive editor Dave Howard and I had one last, spectacular three-hour meal. Wylie patrolled the room, accepting good wishes and condolences, making sure that even in those final weeks, the experience was memorable.

If you're in New York, check out Alder, Wylie's other place. And enjoy his contributions to Popular Mechanics, which we hope will entertain, challenge, and delight as much as I know his food will continue to do, whatever he does next.

RYAN D'AGOSTINO,

EDITOR IN CHIEF



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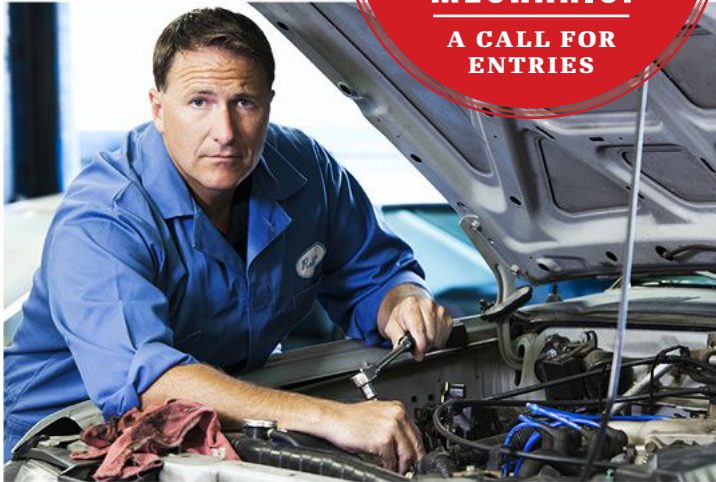


PREAMBLE

CONTEST ANNOUNCEMENT

AMERICA'S MOST POPULAR MECHANIC:

A CALL FOR
ENTRIES



A viable candidate.

We need your help to find the best car mechanic in America.

When your power steering quits on you the day before you're supposed to go on a road trip, is there someone who can always fit you in? When it's time for a tuneup, do you have a guy you trust—not only to be able to diagnose and fix any problem but at a fair price? Who is the mechanic you wouldn't mind getting a beer with, just to sit down and talk about fan belts?

Popular Mechanics is on a nationwide search for the best auto mechanics, the people who ply their trade with efficiency, ingenuity, care, and fairness in the service of our vehicles. We need your help finding them.

HOW TO NOMINATE SOMEONE

Go to popularmechanics.com/most-popular-mechanic by February 15 and tell us about your favorite mechanic in 200 words. If you have a photo, we'll take it. Judging will be at the editors' discretion, based on the quality of the entries and the merits of the mechanics. Popular Mechanics' Most Popular Mechanics will be featured in a later issue—convenient for proudly hanging in garages everywhere.



BERTHA: AN UPDATE

In our October story on Seattle's stalled Bertha tunnel-boring machine ("The Tunnel"), writer Christopher Solomon reported that the project's directors planned to plow through a protective wall and settle Bertha's head into a rescue pit where it could be repaired by the month's end. Bertha hit yet another snag when the new drilling turned up a deposit of shells, requiring two weeks of archaeological investigation. They're back on track now. Tests for the repaired machine are planned for this month, with new tunneling planned for late March.

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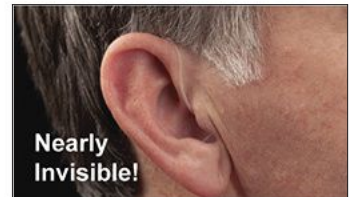


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HOW YOUR WORLD WORKS

The *Pieter Schelte* in sea trials off South Korea. It's now in Rotterdam for final outfitting.

407 ft

Helicopters will help ferry a maximum of 571 crew members aboard.

1,253 ft

The ship's draft, or hull depth, ranges from 32 to 82 feet. Water is pumped in and out of the hulls to raise and lower the decks.

THE BIGGEST SHIP IN THE WORLD

The *Pieter Schelte* is the first boat large enough to remove abandoned oil rigs all at once. Which is good, because there are a lot of them.

BY TIM HEFFERNAN

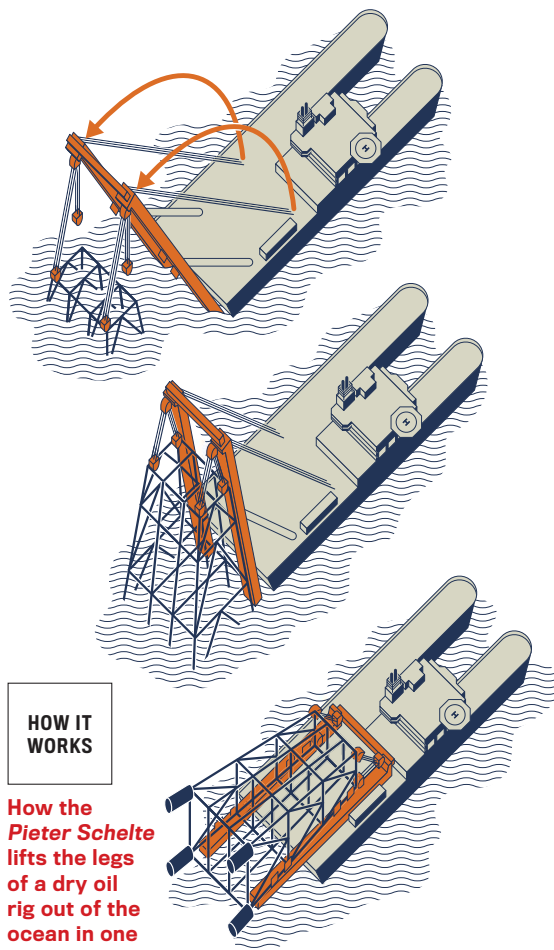
OFFSHORE OIL PLATFORMS FACE AN EXISTENTIAL crisis similar to the rest of the world's: They're in trouble when the oil runs out. But whereas people can turn to other forms of power, rigs are doomed. If they're in the Gulf of Mexico, they'll often be sunk in place for marine life to colonize. (Quite successfully too. A recent study found that rigs are among the most productive fish hatcheries on the planet.) But by law, the dry rigs in the North Sea oilfield, Europe's largest, must be completely removed. Until now this has meant a long process of piecemeal dismantling, but this summer, when the Dutch company Allseas' newest ship, *Pieter Schelte*, goes into service, the job will get much simpler.

The *Pieter Schelte*'s enormous size allows it to lift and remove entire North Sea oil rigs in a single operation. A process that currently takes months, or even years, will be accomplished in days.

To do a heavy lift on the water, you need to keep two things stable: the object being lifted and the device doing the lifting. Neither is overwhelmingly difficult in a sheltered harbor, or when the object isn't all that heavy. But the North Sea is no harbor, and an oil rig is heavy by any measure. The topside alone—the above-water portion where the living quarters and mechanicals reside—can weigh more than 48,000 tons, and the jacket, or the legs that support the structure below the surface and attach to the seabed, can be hundreds of feet long and weigh more than 25,000 tons.

An automated dynamic-positioning system keeps *Pieter Schelte*'s frame stationary in the notorious North Sea currents. When it's time to lift a topside, the ship maneuvers so that the oil rig stands between its hulls, almost touching them. Eight immense arms slide out from the decks and clamp the topside (which was previously cut from the legs) in an unbreakable hydraulic grasp. To eliminate the tension created by the ship's yawing and pitching on the water, the clamps adjust constantly with the waves. Ballast water is pumped out of the hulls, lifting the ship and topside, and both bob free like the world's largest cork.

Removing a jacket is a different challenge, since



HOW IT WORKS

How the *Pieter Schelte* lifts the legs of a dry oil rig out of the ocean in one piece.

1 The 540-foot lift arms rotate vertically off the stern, and cables are attached to the jacket.

2 The jacket is winched upward and anchored to the lift arms.

3 The lift arms rotate back to horizontal, levering the entire jacket onto the deck.

the torque involved in rotating such a huge structure is enormous. A pair of lifting beams 540 feet long tilt down from the ship's stern, and the jacket—previously severed at the seabed—is winched tightly against them. When the beams tilt up again, the entire jacket ends up lying flat on the *Pieter Schelte*'s deck: the Eiffel Tower on a sunbathing cruise. All in a matter of hours.

The *Pieter Schelte* took eight years to build, and that timing is no accident. Over the next 25 years, numerous tapped-out North Sea oilfields will need their abandoned rigs removed, with more rigs waiting to be installed in new sectors to replace them. The *Pieter Schelte* can do that too.



HOW TO RECYCLE AN AIRCRAFT CARRIER

After 21 deployments, the U.S.S. *Constellation* was retired in 2003. For

12 years the 61,981-ton ship just sat there, patiently waiting for an influx of private funds to turn it into a museum. That didn't happen, so this winter the *Constellation* was towed from Puget Sound, around the southern tip of Chile, and up to the International Shipbreaking company in Brownsville, Texas. After flushing the tanks and lines of fuel, ISB will remove the superstructure (the top level, including the flight deck), then harvest the high-value piping. The stern and bow will be torch-cut into steel panels that weigh as much as 20 tons, then trimmed into manageable pieces with hydraulic shears. The metals will then be sent to mills to be melted down and repurposed for commercial use. Which means your next can opener could be battle-tested. —LOULOU FORD



Diamonds & Steel

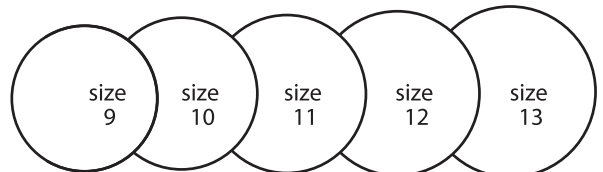
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A SCIENTIFIC COMPANION TO ...

BLACK SEA

JUDE LAW STARS IN THE NEW MOVIE *BLACK SEA* (out January 23) as a moody and recently laid-off submarine captain hired to find Nazi gold entombed in a U-boat at the bottom of ... the Black Sea. The characters may feel a little familiar, but the movie is good. Entertaining. And it brings up some fascinating science, which we consulted with leading experts* to explain. Just be ready for a few minor spoilers. — CAMERON JOHNSON

1 PLOT POINT: Miraculously, the German sub did not rust away.

WHY NOT? The Black Sea is a combination of fresh water and salt water. Because of its higher density, the salt water sinks to the bottom and remains mostly separate from the fresh water above. This means that air acquired through the waves on the surface can never make its way to the salt water below. Without oxygen, the deeper water serves as a natural preservative for metals.



2 PLOT POINT: Escape suits, which inflate to bring crew members quickly to the surface, don't cause the bends.

IS THAT REALISTIC? Submarine Escape Immersion Equipment (SEIE) fills with CO₂ to ascend at a rate of 2 to 3 meters per second. Because the submarine was pressurized to a level equal to the surface's, the bends are not a threat. But exploding lungs could be. According to Boyle's law, as pressure decreases, volume must increase, so as the crew surfaced (from 350 meters, a 35-fold pressure increase), they would have had to exhale—reducing the amount of air in their lungs as it gained volume. If you happened to be screaming, you'd be all set.

3 PLOT POINT: After decades underwater, the German sub was filled with deadly chlorine gas.

COULD THIS HAPPEN? It's possible. If any water reached the battery compartment, the electrical current would cause electrolysis, a chemical reaction that separates the water's molecules (see below). Sodium, hydroxide, and hydrogen aren't noxious, but breathing chlorine gas will kill you. Fortunately, this is rare. And if it did happen, after seven decades the chlorine gas would have become harmless.



4 PLOT POINT: A 4-ton winch gets jammed trying to pull 200 gold bars across the seafloor.

AREN'T THINGS LIGHTER UNDERWATER?

People are, so you might think gold would be too. And it is, but not by much. Denser objects are less affected by buoyancy. Since gold has a density of 19.3 grams per milliliter and water pushes back with its own density of 1 g/ml, the perceived density of gold in water is 18.3 g/ml, or 5.2 percent less than above water. Therefore, 200 standard gold bars (27.34 pounds each on land) would weigh 5,183 pounds underwater, or just over 2.5 tons. Maybe it was a cheap winch.



*With thanks to Geary Albright at James Madison University, George Maul and John Windsor at the Florida Institute of Technology, and James W. Murray at the University of Washington.

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IN PRAISE OF THE PLANCHA

It's a fancy name for a griddle. It's also the most useful heat source you can install in your kitchen.

BY WYLIE DUFRESNE

PLANCHA IS SPANISH FOR "METAL PLATE," AND LEST it seem like some kind of unnecessary, highfalutin equipment, let me clarify: It's a griddle—a big metal slab with a heat source under it, either electric or gas. The first time I ever saw a plancha in a professional kitchen, at Jean-Georges in 1996, I couldn't figure out why a serious chef would want one. But I ended up loving the thing, and I've had several at every restaurant I've run since.

The plancha is an incredibly simple piece of kitchen equipment: The metal plate is usually stainless or A36 steel, which is used in construction because it's strong but easy to machine and weld. The genius is that once the plancha's steel reaches the temperature you've set, it provides a completely even, consistent heat source across the entire surface. It doesn't fall off toward the edges. There are no hot spots. Your pan never heats unevenly. Because the plancha is the pan. More important, it has a lightning-fast recovery time. This means that after you put cold food on the hot metal, the plancha rises right back to the correct temperature quickly, like a fryer does. Rapid recovery time provides more control and reduces the likelihood that the food will stick.

I have a built-in griddle from Viking as part of my stove at home, and I can't get enough of it. A few months ago I cooked 18 pounds of bacon for a wed-



Dufresne demonstrates one of the virtues of the plancha: All the pancakes are ready at once.

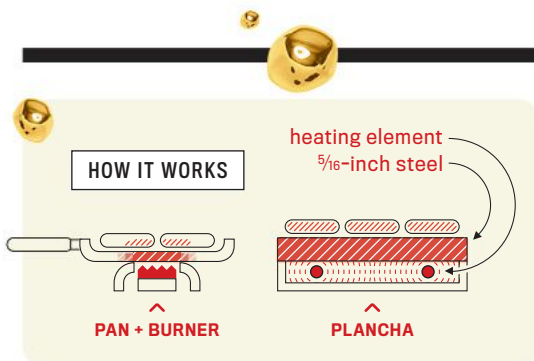
ding brunch, and I didn't have to stop once to deal with the grease. All the rendered fat slid directly into the drip pan in front, and I cleaned it up after the fact. Built-in planchas are incredibly useful when you need to cook a lot of food for a lot of people at one time, or when you need to play the part of a short-order cook for picky kids, as I often do. You can cook a half-dozen dishes on it at once, then clean only one surface.

If I have one big regret about my home kitchen renovation, it's that I didn't allocate more of my range to the plancha; mine is the size of two burners, and I could easily use one that's twice as big. I've been wondering for years why more home cooks don't have one of these surfaces, and, best I can figure, people think they need the burners. They don't want to give them up to make room for a big, weird slab of metal. Here's my opinion: Give up your burners.



HONORABLE MENTION: The Grill Pan

If you're not reconfiguring your range anytime soon, get a stovetop grill pan, such as the cast-iron griddle from Lodge (\$50).



A Guide to Plancha Thermodynamics

Cooking depends on the transfer of heat, and every cooking method transfers heat into food a little differently. A plancha works through conduction, the motion of energy through and between solid objects. As the plate heats up, energy is transferred between adjacent steel molecules. Some of that energy is released into the air through a process called convection, but in planchas with thick steel— $\frac{5}{16}$ inch in the case of the Viking 5 Series, which we modeled at left—most of the heat sticks around to cook your food. This makes for a surface free of hot spots. And a chef free of exasperation.

Your next beer. Just tear open, pour into a pint of seltzer, and give it a stir.

MEANWHILE, IN BEVERAGE NEWS...

100% BEER (FROM CONCENTRATE)

A new product lets you make a fresh beer the way you make a K-Cup of coffee. But do you really want to?

BY MATT GOULET

IF YOU'VE EVER TASTED A MILLER LITE, YOU KNOW IT TAKES a lot of water to make beer. That water is heavy—8½ pounds per gallon. Which means that there's a huge monetary and environmental expense in transporting and distributing kegs and cases around the world. But in 2008 Pat Tatera of Pat's Backcountry Beverages in Golden, Colorado, came up with a solution: Add the water *after* you ship the beer.

Previous efforts to concentrate beer have involved removing water from full-fledged brews, taking away much of the beer's flavor in the process. Tatera, a chemical engineer and home brewer, came at it a different way. He devised a process he calls nested fermentation, whereby a beer is brewed in the largest amount of malt and with the least amount of water that the yeast can survive in and still effectively ferment. That beer is vacuum-distilled, which means the air pressure is removed and the alcohol from the brew is evaporated, extracted, and set aside for later. Left behind is a thick, nonalcoholic beer that gets brewed with a new batch of malt and yeast to make another, highly alcoholic, beer. The process is repeated several times before the syrup and the alcohol removed in each batch are combined to create a fluid that's 58 percent alcohol by volume per 50-milliliter packet. And looks like motor oil. There are three ways to turn the syrup into a real beer. You can add a packet of the company's 1919 Pale Rail ale or Black Hops IPA-style concentrate to a pint glass of



cold soda water, or run it through a home soda maker. Or you can take it on the go and mix still water and the concentrate in Tatera's patented carbonator—basically a SodaStream in a Nalgene bottle. When reconstituted, you've got a craft beer that can stand up to traditional brews. Really. (See left.)

The company is introducing yet another way to dilute its syrup with the release of a reconstituting tap later this year, meaning that beer from concentrate could be on draft at the bar right next to traditionally made brews. It'll be the most flavorful watered-down beer you'll ever order.



THE TASTE TEST

By Dave Arnold, bartender and author of *Liquid Intelligence* (Norton, \$35) "Conceptually, kudos to these guys for pulling off such a crazy idea. My bartenders could make an interesting cocktail using the syrup as bitters. You get a nice head on the beers when you stir them up in the glass. The Pale Rail tastes like a beer. It's definitely not the worst I've ever had. Sort of like Yuengling. That is the better of the two. They hopped the hell out of the Black Hops. It was hard for me to taste it. It's over-carameled, with a candied flavor at the end."

COCKTAIL SCIENCE!

Shaken Versus Stirred.

By Jackson Cannon, owner and lead bartender at The Hawthorne in Boston

SO YOU WANT TO MAKE A COCKTAIL. START WITH



MIXER?



SHAKE.

WHY? Shaking pulverizes egg and milk, incorporating them into the cocktail. It also imparts air bubbles, which give the cocktail a foamy surface, cloud the drink, and make for a lighter taste on your tongue.



STIR.

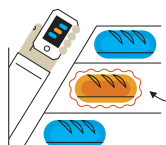
WHY? Stirring chills the drink and incorporates all the ingredients without letting air in, so their original flavors aren't disrupted. It yields a clear drink that is silkier on your palate.

THE CASE FOR INFRARED

New heat-sensing attachments for your phone are so much fun, you won't care if they're useful. (They are.) BY DAN DUBNO



Contributor
Wylie Dufresne
cooking
pancakes for
the photo on
page 18.



Unnecessary but enjoyable ways to use your new thermal sensor: dominating hide-and-seek • picking the freshest bread at the bakery • determining where the fewest people touch the bathroom-door handle • instantly knowing who's nervous

I WAS IN AN M1A2 ABRAMS main battle tank that I first discovered how to see properly. The U.S. Army Armor School had invited me to spend a day in its simulator in Orlando, Florida, and, after looking through the commander's thermal camera unit, it occurred to me that I should have one of my eyes replaced by a cybernetic thermal device. The imager allowed us, day or night, to penetrate camouflage and clearly observe adversaries glowing several thousand feet away.

For the past two decades, civilian infrared options have been bulky and expensive, used mostly by fire departments locating people in burning buildings and contractors identifying poor insulation and overheated wires. But thanks to significant innovations in infrared chips, called microbolometers, two new thermal devices are available—and actually affordable—to folks like you and me. And they fit right on your phone.

The **Flir One** (\$350) offers the most elegant solution, sliding onto an iPhone (only the 5 and 5s, for now) like a case. Its two cameras merge an 80 x 60-pixel

thermal image with a black-and-white VGA (640 x 480) picture, so it's easy to know exactly what the heat images are showing. When I took a shot of myself reenacting Munch's *The Scream*, the camera highlighted a hot burst of white coming out of my mouth, my red cheeks, and the orange-yellow of my cooler arms.

At \$200, **Seek Thermal** is more affordable and smaller, and offers higher infrared resolution (206 x 156). Sadly, though, Seek doesn't merge heat images with actual photos. This can make it hard to recognize what you're looking at, like when I struggled to distinguish among hot electronic components in my friend's crowded workshop. But Seek makes up for this with a wider field of view and easier usability. The half-ounce unit plugs in to any micro USB slot or iPhone Lightning connector. Seek claims its sensor is sensitive to thermal signatures in the 7- to 13-micron range, and that it can differentiate temperatures from minus 40 C to 330 C (minus 40 F to 626 F).

But the real question: What to do with these things? You can be practical and check pipes for leaks, but you might as well have a little fun. I've been using mine to spot raccoons or to test the surface temperature of my grill. According to Seek and Flir, this is only the beginning. The technology will continue to get smaller, cheaper, and more powerful—and I'll be able to see a glowing world with vision like a tank commander's without giving up one of my eyeballs.



THE 15-SECOND REVIEW: SLEEP TRACKERS

WHAT THEY ARE: Devices that improve sleep habits by recording pulse, respiration, and sleep quality. The **Withings Aura** (\$300) uses a sensor the size of a hand towel that slides under the mattress, and has a nightstand alarm clock that wakes you with a soft light. **Beddit Sleep Monitor** (\$149) is a thin strip that sticks to the mattress, under your sheets, and pairs with a phone app.

WHY YOU MIGHT WANT ONE: The wake-up is timed to the ideal part of your sleep cycle. For once I wasn't groggy.

WHICH ONE YOU SHOULD GET: Withings had a gentler wake-up, and white noise that helped me fall asleep. Beddit was easier to set up, but it didn't seem as accurate. — CAMERON JOHNSON

NEW FINDS

"The year may seem young, but it'll be gone before you know it," says PopularMechanics.com Site Director **Thomas Houston**. "Keep yourself focused with a clean workspace, a few smart digital accessories and a strong coffee."



1



2



4



3



1. QUELL & CO SPOOL DOCK

The Quell & Co spool dock is beautifully handcrafted and built in the USA—it looks and feels great sitting on your desk. This innovative dock works with everything from the latest iPhone 6 to the iPad mini.

www.quellandco.com

2. STUMPTOWN COLD BREW

Yes, you can make your own cold brew, but there's no more convenient way to get a great iced coffee than grabbing a Stumptown Cold Brew. Perfectly smooth, impeccably caffeinated.

buy.stumptowncoffee.com

3. SMARTER EMAIL: MAILBOX APP

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www.mailboxapp.com

4. HERO4 PORTABLE CAMCORDER

GoPro's new Hero4 portable camcorder ups the specs on the company's super-portable and -rugged video cameras. You'll be able to shoot eye-catching 4K video at 30fps, perfect for capturing everything from your skydiving attempts to floating around in your pool.

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A QUICK LESSON IN SAFETY.



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¹ Government 5-Star Safety Ratings are part of the National Highway Traffic Safety Administration's (NHTSA's) New Car Assessment Program (www.SaferCar.gov).

² Based on awards received in the past 12 months, ending October 2014.

Do you have unusual questions about how things work and why stuff happens? This is the place to ask them. Don't be afraid. Nobody will laugh at you here. Email greatunknowns@popularmechanics.com. Questions will be selected based on quality or at our whim.

**GREAT
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**HOW YOUR
WORLD
WORKS**



WHY ARE BRICKS THE SIZE THEY ARE?

WHY NOT MAKE THEM EVEN, LIKE, TWICE AS BIG, WHICH WOULD CONCEIVABLY CUT CONSTRUCTION TIME IN HALF?

A WHY STOP THERE? WHY NOT MAKE EACH BRICK THE SIZE OF a typical suburban home, hollow it out, bash an entrance and some ventilation holes into it with a sledge hammer, and have people move right in? That would be a time-saver, for sure.

In fact, brick sizes do vary, though the overriding constraint is that a brick must fit readily into a mason's hand, which rules out the one-brick-abode idea, and ensures that the mason is able to deploy said brick upside the head of anybody who would suggest such a thing, no matter how much sense it might make after a couple of beers down at the ole Popular Mechanics Pub.

Turns out that bricklaying is both art and science, with the science originating in a motion study performed in the early 1900s by Frank and Lillian Gilbreth, who sought to optimize this repetitive task by identifying and eliminating inefficient techniques. Thanks in large part to the Gilbreths' analysis, an experienced, modern-day mason can lay as many as 2,700 bricks

a day using their method. That's thought to be as good as it's going to get, productivity-wise. So back to the question: If 2,700 a day is the cap, why not make each brick larger, thereby covering more territory?

To some extent this has happened, for reasons of both efficiency and aesthetics. Larger buildings, for instance, can look downright silly if they're constructed with regular bricks. Still, standard, or modular (as they're known to those wise in the ways of bricks, like Brian Trimble, regional vice president of engineering services at the Brick Industry Association), bricks continue to dominate the trade. The term modular derives from the fact that construction practices have for the most part been standardized around modules of certain sizes—a common one is 4 inches. That means that, ideally, measurements and components in a design should all be multiples of 4 inches, which cuts down on the amount of costly custom fabrication required. A standard mortar joint is $\frac{3}{8}$ inch. Each modular brick is $\frac{7}{8}$ inches long. Do the math and what do you get? Eight inches—a magical multiple of four. Sure, you could make a 12-inch brick or even a 16-incher, but by that point they tend to get so heavy that they may violate union rules and pose a threat of repetitive-stress injuries, to say nothing of injuries to writers who dare challenge the established order.

If the earth is rotating at about 900 mph, why can't I get in a helicopter and rise up 2,000 feet (to avoid buildings), wait about 3 hours, and then set down in California?

Why don't high divers consistently miss the pool, which ought to rotate out from under them while they're in the air? Why doesn't your dog end up in your neighbor's tree every time it leaps to catch a Frisbee? Why is an unremitting 900-mph wind not peeling the face off anyone crazy enough to venture

from his durable new BrickMansion™ without the protection of a space helmet? Because, you see, we're all along for the ride on this crazy planet we call Earth.

The planet and everything on it—divers, dogs, giant hollowed-out bricks—are always rotating together at the same rate, so in relative terms, we're all standing still. That includes the atmosphere. Take off and hover in a chopper and the earth spins, you spin, the sky spins, the helicopter spins, and at the end of 3 hours you're still where you started relative to the ground below. So the next time someone accuses you of slacking, remind him or her that while it might appear to the untutored eye that you are reclined inert on the sofa with a cooler at the ready and your feet propped up on a giant wheel of cheese, you are actually moving through your day at a very brisk and undeniably productive 900 mph.

Is there any way to capture the gigawatts of energy in a lightning strike for power generation?

Certainly there has been informal research. Typically, it has involved exposed ground, a 9-iron, and a fricasseed corpse in a stupid-looking visor and spiked saddle shoes. But here's the thing: While lightning is excellent for lighting up golfers, climbers, park rangers, and their outdoorsy ilk, it is far less efficient at lighting your handsome new single-brick residence. In 2007 one startup company did experiment with a so-called lightning farm outside Houston, but soon ditched the idea as unworkable. That's because there's a big difference between power and energy. A common lightning bolt contains about 1 billion joules of energy, enough to light a single 60-watt bulb for two months or so, though most of that is lost to things like its own thunderclap and the warming of the air around it. Frankly, Gilligan could do better than that on his bamboo generator-cycle.



ever recorded, leaving scientists to speculate that the virus has mutated to become more contagious—and much more dangerous.

According to Mark Pallansch, director of the division of viral diseases at the Centers for Disease Control and Prevention, EV-68, like any enterovirus, “is highly variable and unpredictable. We don’t know what will happen next year.”

Such variability makes vaccine development tricky. Eckard Wimmer, a virologist and distinguished professor of molecular genetics and microbiology at Stony Brook University, says that although “it’s not known whether or not the genome of the virus has undergone changes that would make it more dangerous than the same virus 10 years ago,” everyone from the CDC to pharmaceutical companies is working hard to find out. The first step is to sequence the new genome. Then, Wimmer says, using a method of computer designing, researchers must change the coding capacity of the virus, which stops it from being able to produce enough viral protein to cause disease. After that, it’s on to animal testing before they can apply for human trials. “We have not yet solved the problem,” Wimmer says, “but we did recently get a new result that is promising. The first stage in our work would take five months to complete. But the next stage would take much longer.”

Not great news. But one more good reason to make sure you’re washing your hands, a simple measure that EV-68 researchers agree is the single best way to avoid it. And which you are probably doing wrong. Instructions below.

THE OTHER VIRUS

PEOPLE WHO
CONTRACTED EBOLA
IN THE U.S. IN 2014

2



PEOPLE WHO
CONTRACTED
EV-68

1,100

100
PERCENTAGE
OF THOSE WITH EV-68
WHO WERE CHILDREN

NUMBER OF
THOSE CHILDREN
WHO DIED

12

BY KIRA
PEIKOFF

LAST FALL, WHEN THE EBOLA frenzy had everyone focused on where a nurse in Maine rode her bike, or what train a New York doctor took in a feverish trip to a bowling alley, many scientists were concerned with something else entirely: enterovirus D68 (referred to as EV-68). It’s a pernicious bug that causes respiratory illness, and in three months it sickened more than 1,100 children in 47 states, killing 12. In some cases,

EV-68 is linked to an unexplained kind of paralysis that appears indistinguishable from polio. The most severe cases of paralysis have left children in wheelchairs, requiring assistance to speak and breathe.

At this point there is no treatment. If you get EV-68, there’s nothing you can do but wait and hope. The disease is not new—the first case was isolated in California in 1962—but it was hardly seen in the U.S. until about five years ago. Last year saw the largest outbreak



THE BETTER WAY TO WASH YOUR HANDS



Soap doesn’t kill viruses. When you wash your hands, soap and friction loosen viruses’ grip on your skin, and water washes them off. This is why you should recite the ABCs while you wash up (just do it in your head)—the extra time encourages you to hit all surfaces of your hands. If soap is just too much work, run your hands under water, which will at least kill bacteria. Bacteria are not osmotically balanced, so if you put them in water, the pressure outside the cell becomes greater than inside and the cell bursts. As a side benefit, you might fool a few more people into thinking you’re not an animal.

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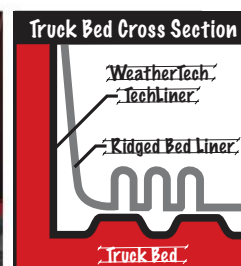
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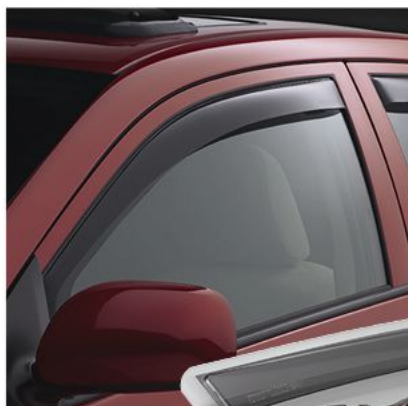
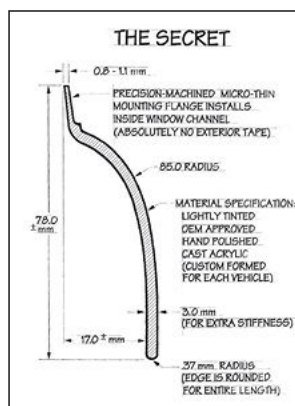
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CARS

By Ezra Dyer

The Best Mustang Yet

So good even the Europeans should be worried.

THE FORD MUSTANG JUST CELEBRATED ITS 50TH BIRTHDAY. Over the years Ford dallied with a turbocharged four-cylinder (the '80s SVO) and an independent rear suspension (the 1999–2004 SVT Cobras). But if you wanted a hot Mustang, the essential recipe was the same last year as it was in 1964: V-8 in front, solid axle dancing around out back.

But after a half-century the Mustang was due for some modernization, and the redesigned 2015 model sends the franchise in a new direction. Independent rear suspension is now standard across the lineup, and a 2.3-liter Eco-Boost four-cylinder joins the V-6 and V-8 models. Turbocharging and independent rear suspension? Is this a Mustang or a BMW?

Don't laugh. Ford is confident enough in its new suspension that it held the Mustang's global launch in Los Angeles, where the bumpy canyon roads sent ▶

2015 FORD MUSTANG

PRICE: \$24,425

MPG (CITY/HWY): 17/28

The Mustang has always represented affordable American performance, and now it can hang with cars twice its price—no caveats necessary.





- UP AHEAD:** 28 Why pushrod engines still matter.
30 Two new luxury crossovers duke it out.
31 The ultimate factory hot rod.





THIS CAR STOLE THE L.A. AUTO SHOW

It's the 2016 Mustang Shelby GT350. The new Mustang's first performance variant, it wears sportier sheet metal and comes specially equipped with active damping, a Torsen limited-slip differential, and a racing-inspired flat-plane crankshaft V-8. Expect more than 500 hp and 400 lb-ft of torque.

the outgoing solid-axle car constantly lunging toward the guardrail. Instead, the new V-8-equipped GT drives more like the old BMW M3 than it does a Camaro, or its own predecessor, for that matter. The 32-valve, 5-liter V-8 is smooth and high-revving, cranking out 435 hp at 6,500 rpm. And the redesigned rear suspension has no trouble deploying that power. The latest GT is also quieter inside than the old one, with the EcoBoost model broadcasting synthetic engine noises through the stereo system. Come to think of it, BMW does that too.

The Mustang's value-leading V-6 returns with 300 hp and 280 lb-ft of torque, but the more intriguing engine is the turbocharged four-cylinder, which has 10 additional horsepower and a healthy 320 lb-ft of torque. Ford is positioning the EcoBoost as a stepping-stone to the GT, offering a performance package that's unavailable to the V-6 caste. But there's some price overlap between an optioned-up EcoBoost and a basic V-8-powered GT. For about \$33,000 you can have amenities or horsepower but not both.

What the four-cylinder model gives up in power it makes up for in mass, weighing 3,500 pounds—200 less than the GT. This

gives the EcoBoost the most balanced front-to-rear weight distribution of any Mustang thus far: 52/48. The EcoBoost feels noticeably more agile than the GT, especially when you pair the four-cylinder with the Performance Package, which brings stiffer suspension, summer tires, and a 3.55:1 final drive ratio. It's a lively, fun car.

In either guise this is the first Mustang that feels as if its chassis could handle a lot more power. Driving the outgoing 662-hp Shelby GT500 was an exercise in fear management, like riding a Radio Flyer wagon down the side of K2. This one should be able to deploy Shelby-caliber firepower on a road course, not just at drag strips.

Overall, the new Mustang makes the Chevrolet Camaro and Dodge Challenger seem especially barbaric. It's poised and polished—perhaps to a fault. Cars of this ilk ought to be a little uncouth, a sentiment quietly affirmed by a Ford engineer at the launch who suggested an easy GT hack. Within the sound-conducting tube that runs through the firewall, there's a piece of sound-deadening foam. To ratchet up the noise, just remove the foam. Refinement is all well and good, but sometimes you need a little less BMW and a bit more Boss.

The new Mustang feels like it could deploy Shelby-caliber firepower on a road course, not just at the drag strip.

A Brief History of Mustang Gratuitousness



1978
Mustang II King Cobra hood graphic



1987
Cheese-grater taillights



2007
FR500GT's humongous rear wing



2012
Boss 302's secondary exhaust

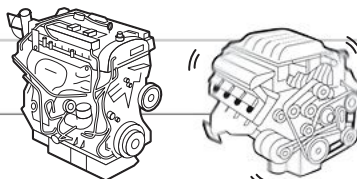


2015
Line lock, which holds the front brakes for 15 seconds of (glorious) rear-tire-destroying wheelspin

And Another Thing!

A barroom rant on pushrods.

Pushrods—they're outdated, right? Overhead cams won. Everybody wants overhead cams, four valves per cylinder, variable blah blah blah. Pushrod engines are a relic from the '50s. You've got a cam down there in the block, only two valves per cylinder, not much you can do with that. Not much except 707 hp. Yeah, the SRT Hellcat Hemi, the most powerful engine Detroit's ever built. That thing's got pushrods, and it seems to do all right on power. Ditto the GM stuff, the Camaros and the Vettes. Fine, pushrod



No pushrods: Yawn. With pushrods: Americal

engines aren't smooth. Fire one up and the car shakes like it's impatient. Because it is. This isn't some computerized make-believe. This is mechanical fact, a reminder that you are piloting a machine that's propelled by explosions. A pushrod V-8 is a visceral thing, a cherished American tradition, and if you think otherwise, you hate excellence.

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For
Evan's
LAND

*Because we need more
places that provide us
with fresh air and water*



We all need places to get outside—to explore, exercise, and recharge. But with America's open spaces disappearing at a rate of 6,000 acres each day, we're at risk of losing our most cherished outdoor escapes. Together, we can change that. Join The Trust for Public Land to safeguard the land, water, and resources that keep us healthy and inspired. Since 1972, we've worked with communities to protect more than 3 million acres and create more than 5,000 parks and natural spaces for people to enjoy. Help to keep this land our land.

Share why nature matters to you: tpl.org/ourland | #OurLand

THE
TRUST
for
PUBLIC
LAND

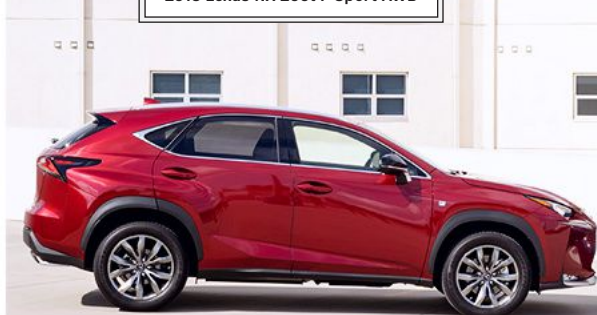


The Perfect Phone Mount

THE PROBLEM: Most phone mounts are clumsy, cumbersome contraptions.
THE SOLUTION: Bracketron's Earth Elements Universal Dash Mount (\$40). Slip a thin, magnetized plate into your phone case and the device sticks like glue to the large mount face without any clamps or adjusting. We like it so much, we gave it a Popular Mechanics Editors' Choice award at this year's SEMA show.



2015 Lexus NX 200t F Sport AWD



PRICE: \$38,905

ENGINE: 2.0-LITER TURBOCHARGED FOUR-CYLINDER; 235-HP, 258 LB-FT

TRANSMISSION: SIX-SPEED AUTOMATIC

WEIGHT: 4,050 POUNDS

EPA FUEL ECONOMY (CITY/HWY): 21/28

2015 Lincoln MKC 2.3-Liter EcoBoost AWD



PRICE: \$40,860

ENGINE: 2.3-LITER TURBOCHARGED FOUR-CYLINDER; 285-HP, 305 LB-FT

TRANSMISSION: SIX-SPEED AUTOMATIC

WEIGHT: 3,989 POUNDS

EPA FUEL ECONOMY (CITY/HWY): 18/26

Luxury Crossover Throwdown

Only one grocery getter can reign supreme.

THE PAST FEW YEARS BROUGHT an onslaught of compact luxury crossovers, all of them European. For 2015 the Lincoln MKC and Lexus NX 200t arrive to do battle with the Euros and, of course, each other. So we drove the NX 200t F Sport and MKC 2.3-liter EcoBoost back-to-back to find out which new four-cylinder quasi-SUV has the best chance of dominating Whole Foods parking lots this year.

The NX is Lexus's first turbocharged vehicle, and its 235-hp, 2.0-liter four-cylinder is sweet, smooth, and has very little turbo lag. But it's also the strongest engine you can get in an NX, since the optional drivetrain is a hybrid system that prioritizes efficiency. Lincoln's standard four-cylinder makes about as much power as Lexus's, but the MKC's optional 2.3-liter EcoBoost generates 285 hp and 305 lb-ft of torque. Those are more like V-6 numbers.

Styling is subjective, but a look at the spec sheets confirms the impression that the Lincoln's shape is more tightly drawn—the MKC is about 3 inches

shorter than the NX but has a longer wheelbase, giving it tidier overhangs. Most of the Lexus's extra length comes from its nose, where the company's signature spindle grille spears forward in an angry snarl. The NX's styling is alien; the MKC's tries not to alienate.

The two cars' interiors exemplify the difference in their personalities. The NX 200t F Sport cockpit is reminiscent of the Lexus IS sedan's, with sculpted, low-slung seats and drilled aluminum pedals. A g-force meter and turbo-boost indicator enliven the information display. The Lincoln, on the other hand, is draped in super-soft leather and trimmed with real wood. Both vehicles use their stereos to artificially doctor the engine note, but Lincoln's system is optimized for noise cancellation, while the Lexus lets you increase the volume on the faux-revving soundtrack. Ironically, Lincoln's approach is more typical of what you'd expect from

refinement-obsessed Lexus.

The disparate philosophies carry over to the driving experience. The Lexus feels sportier, with its six-speed automatic adopting more aggressive shift points in response to cornering loads (in other words, it knows when

you're hustling). The Lincoln is silent and refined, its Continuously Controlled Damping system adjusting the suspension every 20 milliseconds. Given the difference in mien, it's a little counter-intuitive that the MKC is the faster car. The Lexus has the attitude, but the

**The Lexus
has the attitude,
but the
Lincoln has the
extra 50 hp.**

Lincoln has the extra 50 hp.

The choice here comes down to expectations. Lexus does a good job at injecting some fun, but ultimately this is a tall wagon based on a front-wheel-drive platform—not a setup that lends itself to sport-sedan pretensions. Lincoln opted for big power and broad appeal, and that approach is a more natural fit for the crossover mission.

More Power! (The Safe Way)

Preserve your warranty with a factory tuner kit.

AFTERMARKET TUNERS ARE HAPPY TO JACK UP YOUR CAR'S HORSEPOWER, but that added performance can come with the risk that you'll void your factory warranty—something you might regret when smoke starts pouring out from under your hood. The solution: dealer-installed factory tuner kits that will give your car some extra go without the potential headache. More and more manufacturers have them, and each kit offers something different.

HONDA PERFORMANCE DEVELOPMENT SUPERCHARGER KIT

In stock form the Honda CR-Z Sport Hybrid doesn't really embrace the "sport" part of its moniker. Honda Performance Development addresses that issue with its supercharger kit (\$5,495, plus installation), which takes the CR-Z from 130 hp up to a much more entertaining 198 hp. The kit—only available for cars with a manual transmission—includes an inter-cooler, high-flow fuel injectors, and a remapped engine-control unit to take advantage of it all. HPD also offers a limited-slip differential and an upgraded clutch to handle the extra power. Put them all together and you've got a CR-Z that lives up to the legendary Civic CRX Si.

TOYOTA RACING DEVELOPMENT SUPERCHARGER KIT

If you've got a Tundra or Sequoia with a 5.7-liter V-8, TRD offers a tempting proposition. The stock

V-8 is rated at 381 hp and 401 lb-ft of torque. Without altering any of the engine's internal parts, the TRD Supercharger (\$3,400, plus installation) allows the V-8 to pump out 504 hp and 550 lb-ft of torque. A 500-hp Sequoia would be quite the tire-smoking family SUV. Nice detail: The blower includes a bypass valve so that it doesn't ding your fuel economy during steady cruising.

FORD FOCUS ST FR1 POWER UPGRADE PACK

The Focus ST is no weakling in its factory form, but the Power Pack (\$1,695, plus installation) torments the front tires with an additional 90 lb-ft of torque—for a total of 350 lb-ft. That's an outrageous twist from a 2.0-liter four-cylinder. The kit includes a new intake, a new exhaust, upgraded spark plugs, and a retuned ECU. You'll need to use premium fuel, but if you're driving an ST, you should be doing that anyway.



The Ultimate Factory Hot Rod: Ferrari 458 Speciale

If you were to make a list of all the things wrong with the Ferrari 458 Italia, it'd be a short list. And "not fast enough" wouldn't be on it. Nonetheless, Ferrari tinkered with its signature V-8 supercar and built the 458 Speciale, a rolling F1 fantasy that adds 35 hp and drops 200 pounds relative to the Italia. The Speciale's 597 hp feels like even more than that, delivered as it is by a 9,000-rpm V-8 centrally mounted just behind your shoulders. The



interior is stripped to bare metal and made of carbon fiber, reinforcing the race-car vibe. Flick the steering wheel Manettino switch to Race and the active-exhaust system bypasses the muffler every chance it gets, uncorking a howl that will haunt your dreams—the sound of a deity's drill bit boring a hole through the universe. It's the kind of car that makes you want to drive everywhere with the windows down, winding it up high enough to trigger the LED shift lights at the top of the steering wheel. Tunnels are an event. So are on-ramps. And downshifts, each one accompanied by a perfect throttle blip from the dual-clutch transmission. It would be a goofy name for any other car, but in this case it couldn't be any more apt. This is as speciale as it gets.

I love every sticky bit of it.

I love seeing the money coming in and the honey going out.

I love turning soaring sales into a smart hire.

I love that every decision rests in these careful hands.

I run on QuickBooks®. That's how I **OWN IT.**





The Satellite 6 Chandelier

SCHOOLHOUSE ELECTRIC & SUPPLY got its start in 2003 reproducing the undulating opal-glass light-fixture shades that, during the Great Depression, found their way from municipal buildings—libraries, city halls, and schools (hence the Schoolhouse name)—into home kitchens and bathrooms. Founder Brian Faherty had been working in real estate in Portland, Oregon, and renovating houses on the side when he noticed that light fixtures were often an afterthought in a home remodel. The cheap, dull lighting people were buying didn't have the character or quality of the most basic fixtures from the 1930s.

He went out searching for the old shades and instead uncovered a stash of antique cast-iron molds used to make them. A family-run lighting factory in upstate New York had held on to the forms well after they stopped using the 150-year-old hand-blowing method for producing glass shades. Faherty restored the molds and, with them, the shade-making process. In turn he created a home-furnishing company, part of Portland's wave of artisanal manufacturers in the early 2000s, that's now based out of a converted 1910 warehouse. In the thick of the recession, and in response to it, Faherty and his two creative partners

expanded their designs from nostalgic fixtures to the Satellite 6 chandelier you see here. Where the shades recall an era that brought good design into functional spaces, the Satellite is a modern, utilitarian fixture. The exposed sockets and mirrored bulbs hanging from a solid-brass rod spun in California, all assembled and finished in Portland, do just what a piece of lighting is supposed to do: allow us to see things. — MATT GOULET

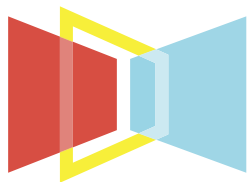
COMPANY: Schoolhouse Electric & Supply Co.

FOUNDER: Brian Faherty

LOCATION: Portland, Oregon



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SKILLS

THE NO-FAIL BREAK

1. Center the cue ball opposite the triangle.
2. Aim directly for the lead ball.
3. Hit the cue ball just above its center to impart spin.

HOW TO

WIN AT BAR GAMES

A guide to using math
and physics to become king
of the neighborhood.

COME FEBRUARY, WHEN YOU'VE SEEN every last movie and burned through every last ounce of holiday joy, and it's still god-damned snowing outside, the only thing saving you from reenacting a scene from *The Shining* is your basement rec room. Or the local bar. Anywhere you can stand indoors, comfortable and warm, and use your wits and a basic understanding of geometry and physics to defeat your friends in pool, darts, air hockey, Ping-Pong, and Foosball. Make no

mistake: Under these conditions, bar games are sporting events. The people who win them are champions. Champions at defeating crushing boredom while sipping an IPA and wearing a cable-knit sweater, maybe, but champions nonetheless. And with our help, you can be one of them.

Billiards table, dartboard, and hockey table courtesy of David Roeder, Blatt Billiards, New York City

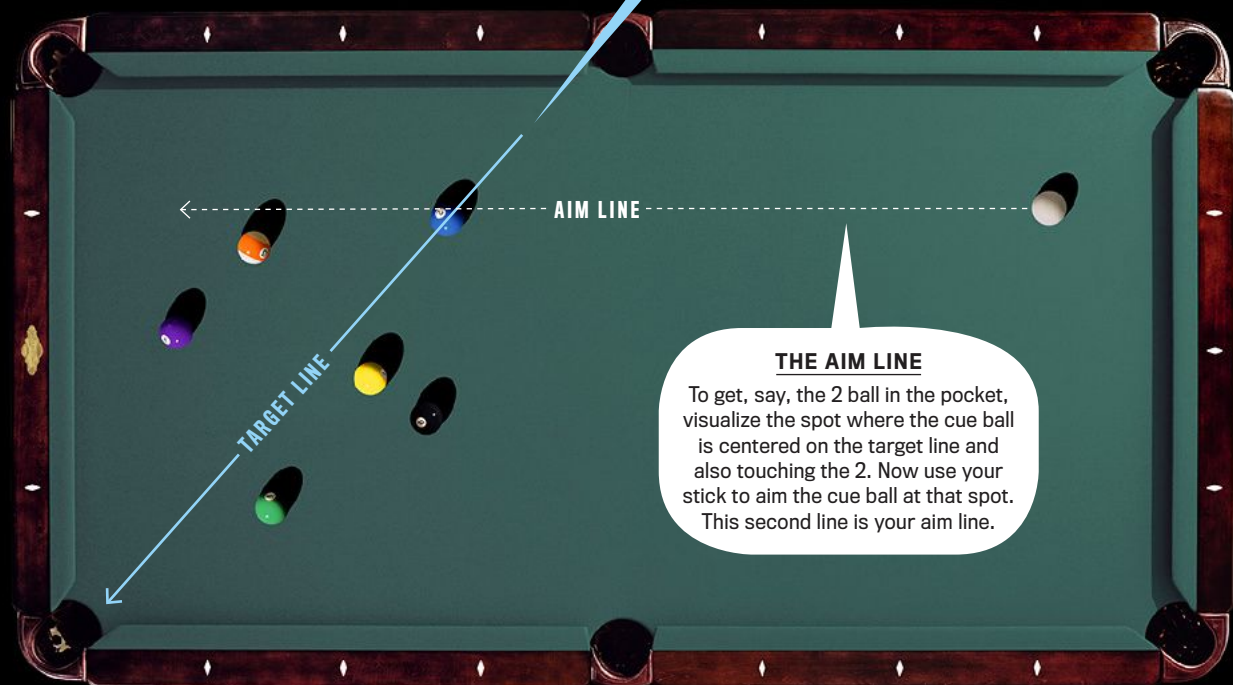
THE RULES OF BAR GAMES: No fighting • No gloating • No puking • All insults shall remain relatively civil. • The first two beers

SKILLS

REC ROOM

THE TARGET LINE

You probably already use your cue stick to make a line from your chosen ball to the pocket you want it to go into. Everybody does this. This is a target line. For any given ball and pocket, there is just one target line.



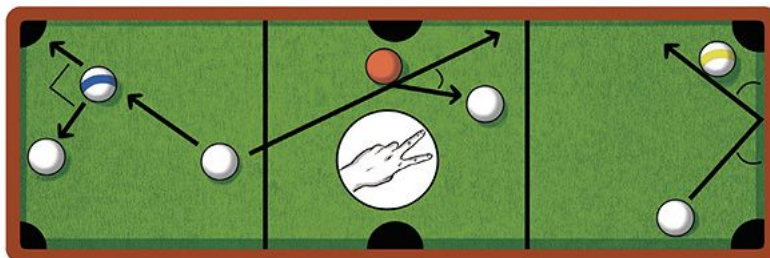
THE AIM LINE

To get, say, the 2 ball in the pocket, visualize the spot where the cue ball is centered on the target line and also touching the 2. Now use your stick to aim the cue ball at that spot. This second line is your aim line.

• POOL

LINEAR MOMENTUM

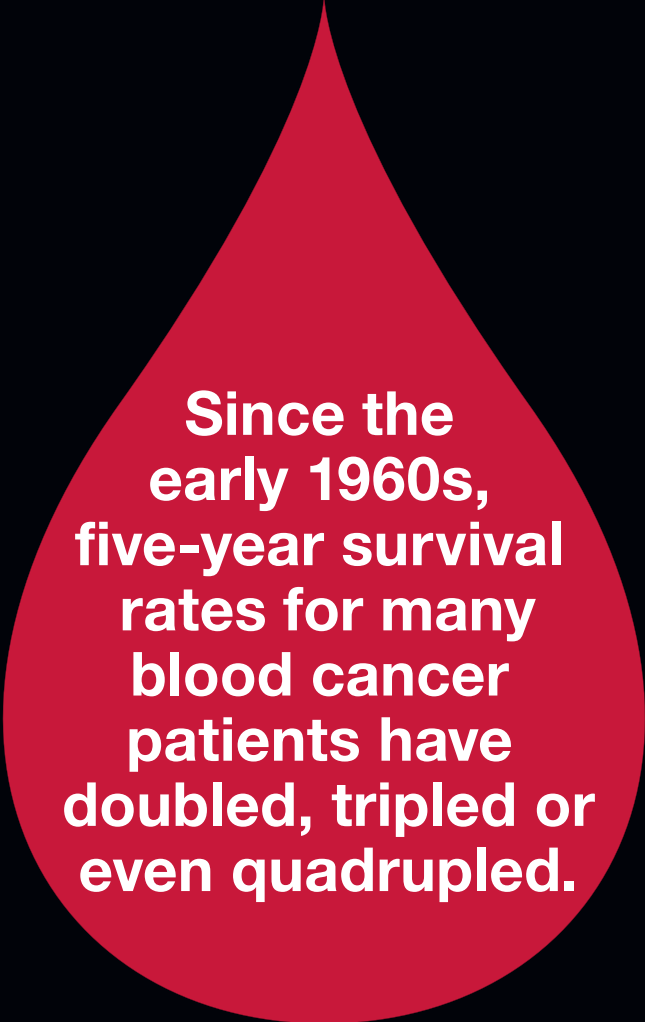
Peel back the layers of fog that stand between you and everything you learned in high school. You may remember such topics as Euclidean geometry and kinetic energy from textbook chapters that featured photos of pool tables. The low-friction, two-dimensional environment of the game—a rectangular felt table that allows smooth-surfaced balls to slide or roll—is an ideal one in which to use these concepts in real life. We asked David Alciatore, professor of mechanical engineering at Colorado State University, for a few tips.



- Knowing what your cue ball will do after it makes contact with an object ball helps you avoid scratching (also, cursing and throwing things). If you strike firmly in the center of the cue ball, it will slide along the felt rather than roll. When a sliding cue ball makes contact with an object ball, the two will always separate at an angle of 90 degrees.
- Now if you hit the cue ball softly and just above center, it will roll instead of slide. When it strikes another ball, its path will divert about 30 degrees. To estimate this, make a V with your middle and index finger and point your middle finger along the aim line. Your index finger will show you the rough trajectory of the cue ball after impact.
- Bank shots are about as simple as geometry gets: When a ball hits a bumper, the angle at which it shoots off mirrors the angle at which it came in. So if you're trying to hit the cue off a bumper, make an aim line from the cue ball to the bumper and reflect it onto the opposite side. Make the angles on both sides match and you're in.

improve performance. After that, it declines by 10 percent with each additional beer. • The behind-the-back thing never works. •

someday is today



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rates for many
blood cancer
patients have
doubled, tripled or
even quadrupled.

we're accelerating cures to save more lives.
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LYMPHOMA
SOCIETY®

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SKILLS

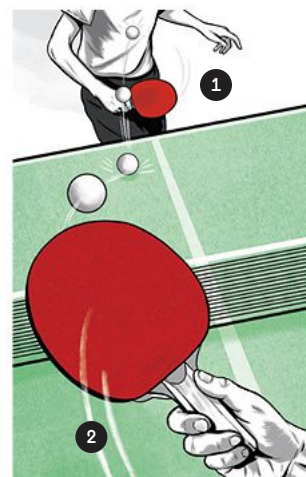
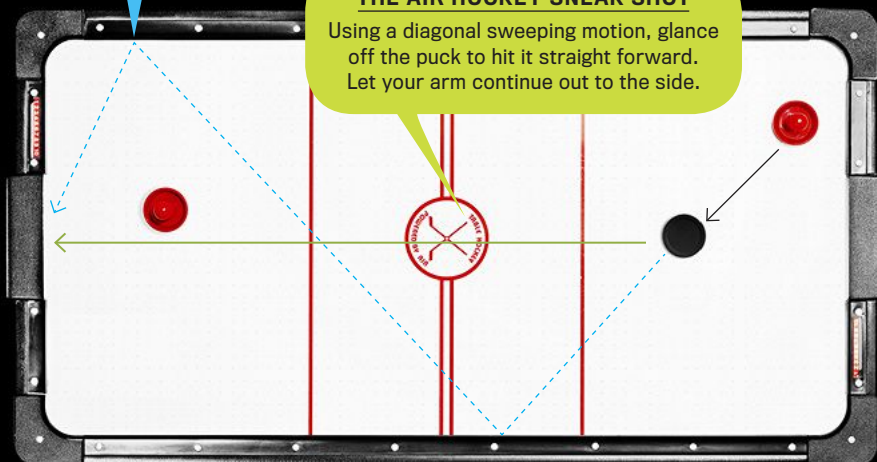
REC ROOM

THE UNEXPECTED BANK

Imagine a horizontal line that extends from your opponent's mallet. Aim a hard bank shot at the side wall behind that line and you're in.

THE AIR HOCKEY SNEAK SHOT

Using a diagonal sweeping motion, glance off the puck to hit it straight forward. Let your arm continue out to the side.



• PING-PONG

SPIN

In Ping-Pong, as in cable news and politics, winning is all about spin. A ball flying through the air is moving in two ways. There's straight velocity, the motion of the ball directly toward or away from you. And then there's spin, the angular velocity of the ball rotating over itself. The latter is what causes the ball to do spooky, spectacular things, like ricochet off the table, over your opponent, and under a chair in the corner of the room. All Ping-Pong players try to give topspin, where the ball rotates over itself, bottom over top, as it's moving toward the other player. This will make the ball speed up after it bounces on the table, jarring the opponent and conferring an advantage.

1. In general, a shot fired into the center of the chest is the most difficult kind to return, so aim for the middle of your opponent's body.

2. To give topspin: Using a paddle with a bit of rubber on it, like the Tibhar Volcano X, push up and over the ball, adding a little extra oomph to counter any spin from your opponent.

• AIR HOCKEY

SPEED

Air hockey is a fast-moving game that, like real hockey, is as much about velocity and guts as it is about technique. To keep up, you need a loose grip that will allow you to move your wrists: Instead of clutching the mallet handle, place your hand over it, with your middle finger in front of the knob and your index and ring fingers behind it. Also: Change up your

shots occasionally. After a long volley, hit a few slower shots to draw your opponent away from his goal. Then, when he's least expecting it, surprise him with a deep bank shot or a bullet that moves in a different direction than your arm (see diagram, above).

If all else fails, try the distraction technique, shouting out facts about air-hockey tables while firing off slap shots. For example, the puck is made of glass-filled Lexan plastic. It weighs a little less than 1.5 ounces. The ridge around the edge is what lets it float on the air coming up from all those little holes. Have you won yet? Tell your opponent his fly is down.

WITH THANKS TO

PING-PONG: Jim Butler, three-time U.S. men's singles table-tennis champion. DARTS: Scott Braese, The American Darters Association No. 1 steel-tip dart thrower of 2014. AIR HOCKEY: Mike Prendergast, technical manager, Valley-Dynamo air-hockey-table manufacturers.

If you have to ask yourself whether you are too drunk to take a particular shot, the answer is yes. • Cheating while someone is buying



THE PARABOLIC ASSUMPTION

A light dart will follow a greater vertical arc, so aim slightly lower than your target so as not to hit too high.



• DARTS

AERODYNAMICS

Darts are like really sharp, slow-moving bullets: They travel on a ballistic parabolic trajectory, arcing up and then down. The harder you throw, the straighter the dart will fly, but you'll have less control. So control your stance. Point the toe of your throwing side toward the board and open your other leg to the side. Limit your movement to the elbow and wrist. Extend your arm about three-quarters of the way and release the dart. Follow through until your finger is pointing at the board. See, it's just like a gun.



To keep a shot straight, find the dart's center of gravity and balance it on your thumb, letting your fingers gently hold it in place.



If you're just starting out, try the Shot 803 Steel Tip Dart in 28-gram weight. It's heavy enough to straighten out a wobbly beginner's throw.



Unless you're playing some weird game, always aim for the triple 20. It's worth 10 points more than the bull's-eye, and it's bigger.

HOW TO WIN AT FOOSBALL AND ALIENATE PEOPLE

In the professional soccer world there exists a style of play known as tiki-taka, in which small, technically skilled players work their way up the field using short, quick passes. You should not try to use tiki-taka to play Foosball. Unless you plan on spending years honing your craft, you will be aggressively bad at it. You will attempt to pass to your midfield 5-bar, and it will bounce off and squirt back into your own net as you pump your

3-bar back and forth. Instead, use your goalie to shoot long shots. No one expects it, and your opponent will not have aligned his defenders, allowing you to catch him off-guard. Also, angle your 3-bar so your guys are all leaning forward. When a pass comes from the back, it will stop under them. This way you can control the ball and hammer shots from close range.

To defend, align your 2-bar so that one guy is covering half the

net. Cover the other half with your goalie. It's simple, but most of the time your opponent won't be able to navigate past it. When you inevitably win, shake your opponent's hand, look him dead in the eye, and tell him, "Tiki-taka is dead." Then walk away and start smoking a vanilla-scented cigarillo while pretending to talk on your cellphone. He won't know what you mean, but he'll know you're dangerous.

— KEVIN ALEXANDER

a round will result in immediate reincarnation as a floor in a truck-stop bathroom. • For the last time, there is no spinning in Foosball.

SKILLS

TAKING STUFF APART

HEAT-DISSIPATION SHEET

Located behind the sensor, this copper-foil sheet passively diffuses heat to keep your camera cool.

MAIN BOARD

This circuit board connects the power ports to the battery and the memory card to the sensor. It's also where you'll find the internal memory. If the lens is your camera's eye, this is its brain.

Our dismantler:
NYU Polytechnic
School of
Engineering
student
Wilson Zhong

THIS WAS A FUJIFILM X30 CAMERA

We took the classic inventor's approach to figuring out how a new compact camera works: We broke it.



FLEXIBLE PRINTED CIRCUIT
These copper ribbons carry information from the sensor to the digital viewfinder (the black cube at left), so you can see what you'll get before you snap.

LENS BARREL AND UNIT
These two pieces arrange 11 individual glass lenses in a line to focus the image you want to capture onto the sensor. Three of the lenses are aspheric (to prevent distortion), and two are made of extra-low-dispersion glass (to enhance sharpness).

X-TRANS CMOS II SENSOR UNIT
"A lens forms an optical image; there's nothing digital," Wang says. "The sensor converts the light signal to an electronic signal." This black square contains millions of tiny transistors, each of which records the light intensity for a single pixel of red, green, or blue.

FLASH CAPACITOR
"This thing shocked me twice," Zhong says. "It stores power for the flash."

IF YOU BUY A FUJIFILM X30 CAMERA IN A STORE, the salesperson will tell you about its short-lag electronic viewfinder. He will tell you that it's undergone a redesign since its previous incarnation, the X20. But he will not tell you the fun stuff: that it contains hundreds of prickly, mysterious parts, dozens of which are hellishly tiny screws and one of which is a capacitor that can still shock you even with the battery disconnected. Wilson Zhong, the New

York University Polytechnic School of Engineering student who helped us disassemble the X30, found all this out the hard way. He unscrewed each of these tiny screws by hand. Then, with the help of electrical engineering professor Yao Wang, Zhong was kind enough to explain what some of these parts do, so you can leave your camera in one piece. It works a lot better that way. So, why did we destroy ours? To, um, see what was inside.

SKILLS

TOOL TEST

BEST
OVERALL



THE PREDATOR OF POWER TOOLS

An abrasive chop saw can cut nearly anything.

WHEN YOU'RE SLICING STEEL REBAR, the resounding clang of metal hitting the floor of your garage might as well be a carnival-game winner's bell. Steel is hard. You could use a hacksaw, an angle grinder, or even a torch to cut it, but an abrasive chop saw is a better choice: Because it uses an abrasive disc instead of a saw blade, it has no teeth to get stuck and can plow through rebar, cast iron, steel pipe, or chunky angle stock. With one of these saws, you could cut yourself a mailbox post—or you could build an entire hot rod. We gathered five 14-inch chop saws, mounted an industrial-grade Norton Gemini Rapid Cut abrasive wheel on each, and chopped through stacks of steel studs and a pile of 1/8-inch-wall steel tubing. Sparks flew. Steel fell. And a winner emerged.

A BRIEF LESSON IN SPARK PATTERNS

Assuming you're wearing safety glasses, the sparks that fly off an abrasive chop saw won't hurt you, but they can become a nuisance. Have a friend take a picture while you make a cut. You should see sparks shooting straight out the back or side of the saw. If they are flying everywhere, try tipping the top of the deflector toward you to direct more of the sparks downward.

For more chop-saw reviews go to popularmechanics.com/chopsaw.

★★★★★

DEWALT D28715 \$200



Vise capacity: 9 3/8 in.

Tube-cut time: 11.14 sec

Likes: This was the only saw that allowed tool-free blade change, and it has a vertical spring behind the head, which makes it easy to move.

Dislikes: A 6-foot power cord is barely long enough to stretch across a workbench, let alone a metal shop.



★★★★★

PORTER-CABLE
PC14CTSD \$120

Vise capacity: 9 3/4 in.

Tube-cut time: 10.3 sec

Likes: It clocked fast cutoff times with very little vibration.

Dislikes: In the down position, the saw head is held in place with a crude chain-and-catch mechanism.



★★★★★

HITACHI CC14SFS \$140

Vise capacity: 11 7/8 in.

Tube-cut time: 10.0 sec

Likes: The Hitachi was the most comfortable straight-handled saw and the easiest to use. The deflector contains sparks well.

Dislikes: Has the same lock mechanism as the Porter-Cable.



★★★★★

BOSCH 3814 \$200

Vise capacity: 8 3/4 in.

Tube-cut time: 13.0 sec

Likes: It's smooth-running and has a wheel cover that provides unfettered access to the arbor bolt when necessary.

Dislikes: Again with the weird chain-and-catch locking mechanism.



★★★★

DRILL MASTER
61389 \$75

Vise capacity: 9 3/4 in.

Tube-cut time: 11.3 sec

Likes: It's got a few rough edges, sure, but it cuts metal like a champ. And it's \$75.

Dislikes: Noticeably more vibration than the other saws.

BEST
VALUE



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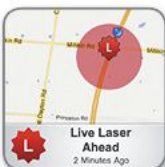
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SKILLS

AUTOMOTIVE



THE KIDS IN THE GARAGE

How to strip, repair, repaint, and rewire an old car—with help from an after-school auto club. Part one of a six-month series.

AERICAN TEENAGERS USED TO WORK ON CARS. It was part of the culture. But in the last few decades, the pastime of messing around in the garage fell off in popularity—cars have become harder to work on (and they need less work), and kids found other pursuits. It may be coming back, though. The best evidence we've found so far is in a 5,000-square-foot workshop at Freedom High School in Freedom, Wisconsin. There, most afternoons, members of the auto club are loosed from the rituals of high school (sitting in grids of desks like crayons in a box, copying notes from the blackboard) and are discovering the rituals their fathers and grandfathers knew: crouching in wheel wells, swinging parts on booms, rotating stripped-down cars on a giant rotisserie.

They also learn skills they can use: metal and rust repair, welding, electrical, mechanical, and body work. How to paint. In the 43 years since the school's automotive program (which also includes classes) was founded, many students have gone on to work in engineering or other skilled trades, and about a dozen have opened their own automotive shops. "They basically learn to take a car apart, fix it, and then put it back together," says Jay Abitz, Freedom High's automotive instructor. Over the next six months, we'll follow the club as it restores a 1974 Oldsmobile Delta 88 and a 1981 Chevrolet Camaro Z28, teaching us a few things along the way.

From left: Nate Hermus, 17; Austin Van Den Eng, 17; and Austin Konkle, 16, strip paint from a Camaro Z28.

Do you know of a great high school auto club? Tell us about it at editor@popularmechanics.com.

HOW TO STRIP A CAR

Tips from the Freedom High School Automotive Program.

STEP ONE ASSESS THE ORIGINAL FINISH

If the car is from the mid-1980s or earlier, it likely has a hard, brittle lacquer- or acrylic-based paint, which you'll want to remove. Most cars made after 1990 will have a urethane- or water-based factory finish, which have higher-quality primer and e-coat, an electrically applied layer of corrosion-resistant paint that you should try to leave on the car, if possible. If you're unsure which finish you've got, apply a sander with light-grit sandpaper. As you sand into the glossy top layer that protects the paint, newer finishes will produce a white dust.

STEP TWO STRIP



For lacquer- or acrylic-based finishes: There are many

strategies for removing these paints, but most are ill-advised. Sanding is a waste of time and money. Chemical strippers can produce hazardous fumes. Abrasive blasting is messy and expensive. A cleaner, safer, cheaper idea is to use a razor blade to flake off the old paint in big chunks, then use a pressure washer to blast off anything that's left.



For urethane- or water-based finishes: If the paint is in good

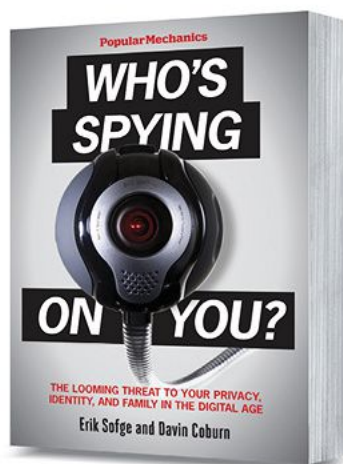
condition, use 320-grit sandpaper or a scuff pad to lightly sand through the clear coat and color coat down to the primer. Stop before you reach the metal, but make sure to eliminate any paint or surface issues—rough spots, peeling or flaking, and rust—before repainting.

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Got questions? Send them to AskRoy@popularmechanics.com.



ASK ROY

Popular Mechanics' senior home editor solves your most pressing problems. BY ROY BERENDSOHN

When we moved in, our new house had that cat smell. We cleaned the carpet and everything seemed fine—until we turned on the heat. Now it's back. What can we do?

It's a rude awakening, in the literal sense of that phrase, when a foul pet odor returns once the heating system comes on. If areas of the carpet were saturated, it's likely that the subfloor is thoroughly stained and the odor is coming from the lumber below.

Here's the bad news: The carpet has to come up, and the subfloor needs to be sealed. The good news is that this is a relatively simple job. Once the carpet is up, use an odor-sealing paint, such as Rust-Oleum's Zins-

ser B-I-N 2 Primer/Stain Blocker/Odor Sealer. This is a soy-based alkyd-resin primer (translation: you should clean your tools with paint thinner) that you can brush over the subfloor and other affected surfaces, such as the backs of radiator covers. While you're at it, seal the baseboard trim and the lower part of the walls, and paint those as well. Then reinstall the carpet. That, and a few scented candles, should take care of it.

The shelves on my bookcase are starting to sag in the middle. Do I have to toss it?

Not necessarily. Obviously, you should start by moving your copies of *War and Peace* and *The Complete Works of William Shakespeare* from the center of the shelf to the side. This will reduce the shelf's downward bend, but you may need to take a second step to fix the whole problem. You can stiffen shelves made of wood, plywood, or particleboard in two ways. The first is to glue and screw a long, narrow strip of wood down the center of the shelf's bottom, like a racing stripe. The second is to glue and nail a short, vertical rectangle of wood to the front edge of the shelf so that it acts like a beam. If the shelf is removable, glue a strip to the back edge as well.

I recently put together a project that called for a power driver, but there were a couple of fasteners I had to screw in by hand. Is there an easier way to do this than switching back and forth between tools?

Power driving is a godsend when you have to add or remove a lot of

screws in a hurry, but you need a hand tool when the work calls for a lighter touch, such as tightening a terminal screw on a light switch.

Klein Tools has a nice, neat compromise. Its Switch Drive is a screwdriver handle with a spring-loaded locking collar and a set of bits that can be transferred to a drill or impact driver. There are two versions: a square drive and a Phillips bit, both in No. 2 size, for \$21; and a set of three nut drivers ($\frac{1}{4}$ -, $\frac{5}{16}$ -, and $\frac{3}{8}$ -inch) for \$42. The bits fit into a spring-loaded collar on the screwdriver handle, and a backward click releases them so you can shift them into a power drill. I was impressed with the fit: It's tight, but you can still easily remove the bit.

What's with the gross, sooty glass on my nice woodstove?

I was recently relaxing in front of the woodstove at my youngest brother's house. I asked him how he keeps the glass so clean, and he said he washes the surface twice a week with a specialized cleaner, Rutland Conditioning Glass Cleaner for Stove, Grill & Hearth, and he burns a hot fire using seasoned hardwood. Besides brightening the glass, the cleaner leaves a protective film that makes the next wash easier. You'll want to apply it with a white Scotch-Brite pad designed to clean ceramic, chrome, and stainless steel. Wipe the residue off with a moist paper towel, followed by a dry one.

There's also the old home-style solution—wiping the glass with a paste made of water and wood ash, then scrubbing with newspaper. Whichever option you choose, don't do anything that will void the stove's warranty.



WHAT'S IN ROY'S GARAGE?

Our columnist on his favorite new tool.

I can't stop talking about the new inductive-charging impact driver and wrench from Bosch (model IDH182WC-102). It prevents the worst moment in any project: when you're busy and your tool suddenly powers down. This driver will not do that, because it's the first tool that easily charges while you work. Its charger emits an alternating magnetic field. Set the tool down on it and a copper receiver coil in the battery converts the field into power. It's fast too. The driver recharges from dead to 80 percent capacity in a half-hour. It costs \$280, but you'll save about that much just on contributions to the swear jar.

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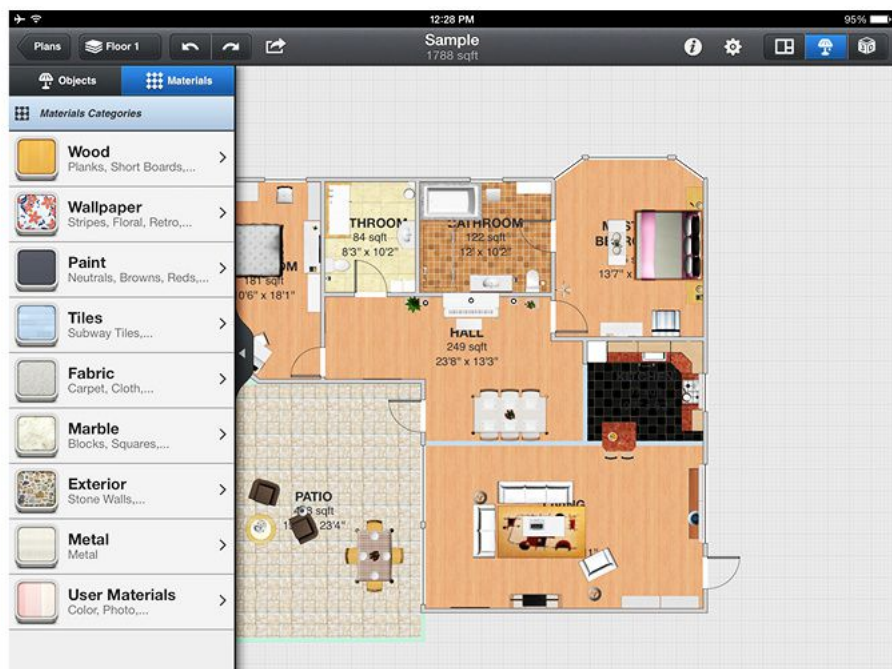
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SKILLS

APPS



Consumer computer programs have come so far since then that we don't even call the majority of them programs anymore. There are Photoshop-caliber consumer CAD programs for desktops, sure, but there are also more than 1,500 architecture apps in the iOS App Store, and almost all of them can be downloaded instantly for less than the cost of a good drafting pencil. I recently spent \$10 for one such app, a 3D planning tool called Interior Design for iPad that came highly recommended. In comparison with that first home CAD package of mine, it's a miracle of sophistication. With it you can use an iPad to create, decorate, and furnish three-dimensional models not just of rooms but of multistory houses—and to enlarge, shrink, tilt, and rotate everything as you go along so you can see what your creations look like from different angles and on different scales. (At one point I worried that I'd erased a roomful of furniture, but then I realized I'd merely supersized the space and wandered under a counter.)

To test the capabilities of these sorts of apps, I decided to see how closely Interior Design for iPad could reproduce our actual kitchen—which we eventually did remodel, at frightening expense, with the help of a professional kitchen designer. During my first hour with the app, I got so angry with it that I was tempted to throw my iPad (in truth, my wife's) into the driveway. The FAQs on app developer Black Mana Studios' website were no help: "We are currently we are working on solution, that will allow to work on all platform much easily." (The company's founder is from Israel, and the chief technology officer is from Russia.) But I calmed down, and in the end produced an impressively accurate simulacrum.

Not that everything worked smoothly. Interior Design includes several thousand elements that you can drag into floor plans—doors, chairs, floor tiles, clocks, air conditioners, toilets, wastebaskets, toys, potted plants. You can move them around; change colors, sizes, and building materials; and even import photographs and blueprints of your own. But some of the elements are exasperating to work with. You can duplicate a custom ottoman, for example, but not a custom window—which means that, if you want to use a dozen identical windows

THE ONE-HANDED KITCHEN RENOVATION

Smartphone and tablet apps let even the most design-challenged play architect. **BY DAVID OWEN**

WAY BACK IN THE 1990s, when my wife and I were first beginning to think seriously about remodeling our kitchen, I bought a software package that was billed as a home version of the computer-aided design programs that architects had begun to use in preference to pencil and paper. I spent a couple of days wrestling with it, but in the end the "plans" I produced were so dumb-looking that I couldn't bring myself to show them to my wife.

From top: Interior Design for iPad's walk-through capability; a sample floor plan; populating the app with furniture and materials.

that don't happen to be exactly like any of the (not entirely standard) ones that come with the app, you have to manually enter the dimensions and positioning details for each one. And although the app will tell you, say, how far the edge of a table is from a wall, it won't tell you how far it is from the counter that is attached to the

At one point I worried that I'd erased a roomful of furniture, but then I realized I'd merely wandered under a counter.

wall—useful information if you're trying to decide what will fit and what won't.

In short, for \$10 you're not getting your own personal interior designer. What you're getting is more like a Roomba with a sketch pad that speaks poor English but can put together a respectable map of your home. In an industry where you can buy a couch for what it costs to hire a professional to recommend that you place it across from the TV, that's a heck of a deal.

Not an iPad user, or just want to try something different? Here are two great, free home-design apps that are available for both Android and iOS.



MagicPlan

This app's strongest recommendation is its ease: You can create a floor plan and measure the dimensions of a room by taking a picture, then use the app to adjust and rotate furniture.

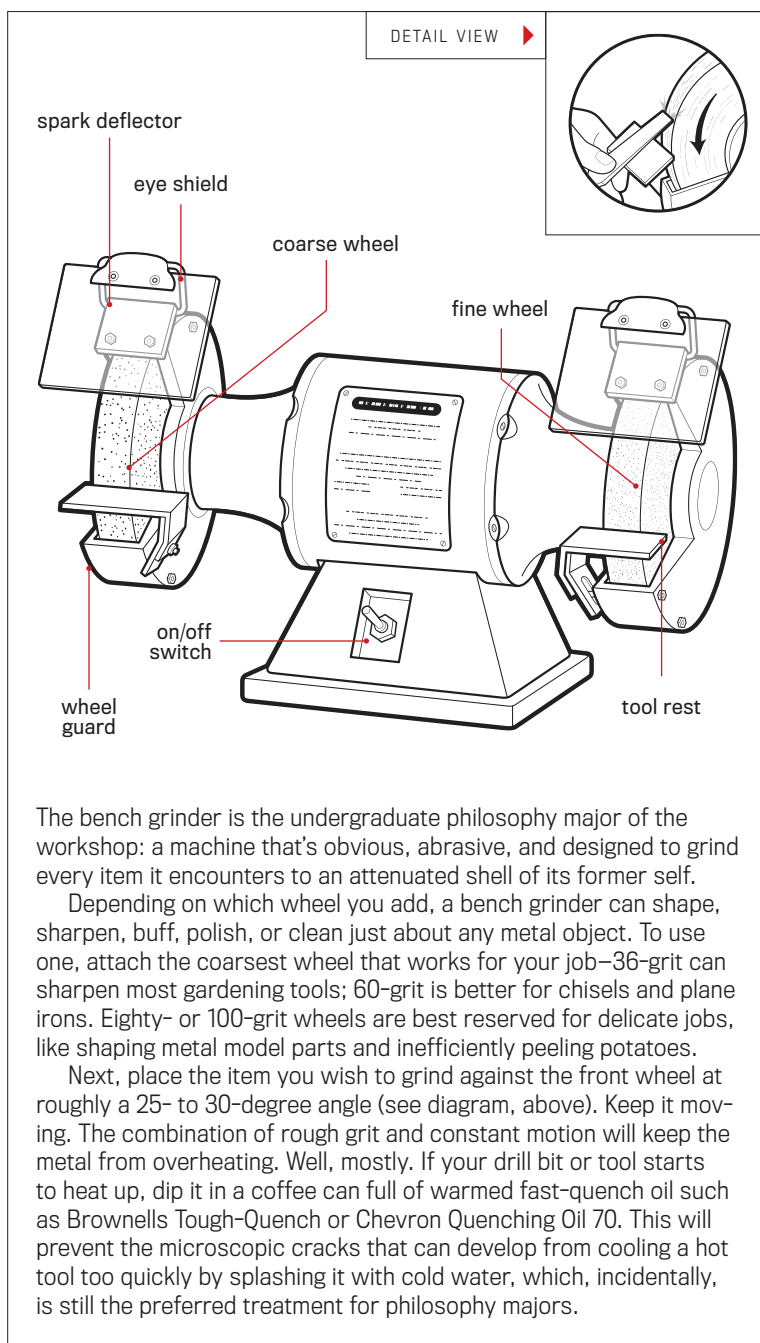


Autodesk Homestyler

Populate plans of your place with models of fixtures and furniture from companies like Crate & Barrel, Ethan Allen, Restoration Hardware, and Kohler. Then link through to buy your piece.

SKILL OF THE MONTH

How to Use a Bench Grinder



BY TIM GRIERSON
AND LAUREN BANS

PHOTOGRAPHS
BY ART STREIBER

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With your host, Ms. OLIVIA MUNN, star of screens large and small, former tinkerer, the funniest person in HBO's *The Newsroom*, and the best reason to see *Mortdecai*, the most strange and wonderful movie of 2015.



Best Scale Shift

The Grand Budapest Hotel

In Wes Anderson's *The Grand Budapest Hotel*, intricate miniatures were built to give a sense of the hotel's magnificence. According to production designer Adam Stockhausen, Anderson envisioned a "hotel that sits on a hill that is not reachable by the regular train. Miniatures happened to be stylistically appropriate to the handmade quality of this film—plus, it allows for a hands-on control of the process and a very physical product." The wood-and-paper mini hotel took a few months to build. "For the details," he says, "they cast repeatable parts. All that window and door detail—they would make one, mold it, and then cast multiples out of resin." The resulting model is striking, like an immaculate relic from a more civilized time. ▼



Russell Crowe in *Noah*.

Best Storm

Noah

Ben Snow, visual-effects supervisor, on creating the chaotic flood scene:

▲ "The Bible says that the waters shot from the ground, so we filmed geysers in Iceland as a reference to create our own CG versions, then added details like mist and spray. For the first wave of the flood, a water simulation helped us create a big wave coming from all sides like a doughnut. Then there were 100-gallon dump tanks and water cannons that we actually fired at the stunt guys trying to climb aboard the ark. Oh, and Hurricane Sandy hit when we were filming. We had to shut down for 10 days. That was sort of ironic."

And the Andy Serkis Award for Achievement in Motion Capture goes to . . . Andy Serkis in *Dawn of the Planet of the Apes*

One great scene in *Dawn of the Planet of the Apes*—a battle between Caesar (Serkis) and Koba—combined existing motion-cap effects with a stunt element straight from *Titanic*. Dan Lemmon, a visual-effects supervisor with Weta Digital who worked on both films, explains:

"When the *Titanic* was sinking, people fell and bounced off of things. That was done largely by using motion capture as a reference and adding digital framing on top. These days, with advances in the kinds of stages and in the stunt rigging, you can get much of the physical stuff in a capture ses-

sion. In the scene in *Dawn*, bombs go off and things explode and start falling over. We got to do tons of stunt work on the motion-capture stage where we'd flip guys around and throw them off heights and bounce them off poles and things. They loved it."



Slaying of the Year

Gone Girl

When Amy surprises Desi with a mid-coital slash across the throat, his blood pours out like a mall fountain. "We used a pneumatic-plunger system," cinematographer Jeff Cronenweth says. "The blood ran up the back of his leg and across through a prosthesis into his neck." The only issue was the ensuing mess—made worse by the fact that director David Fincher is notorious for wanting multiple takes. "Every time it happened it would take about two hours to do cleanup," Cronenweth says. "You have to get the blood off the actors right away, or eventually their skin would start turning pink. You have to change the bedding and clean the furniture and the carpet. We did about 12 takes altogether."

background. Specific color choice depends >

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THE
AWARDERS
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OSCARS



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2000



TOM HANKS
1992

BEST ALIEN (HUMAN EDITION)

Under the Skin

Most movie aliens don't look like Scarlett Johansson. The one in *Under the Skin* didn't either, at first. "We tried false teeth and things like that, but in the end we decided not to touch a thing," says senior special-effects supervisor Mark Curtis. Instead the shock of her alienness comes in the finale, when her human disguise gives way to her featureless black self. "We had to create a replica skin of Scarlett," Curtis says. "We took a full-body scan from her, and one from the actress who was going to wear her skin. We converted Scarlett's data to a computer-controlled machine, which basically milled out the shape of her body in plasteline. We added in all the detail and it was then dressed onto the 'alien' actress after she was body-painted black." ▼

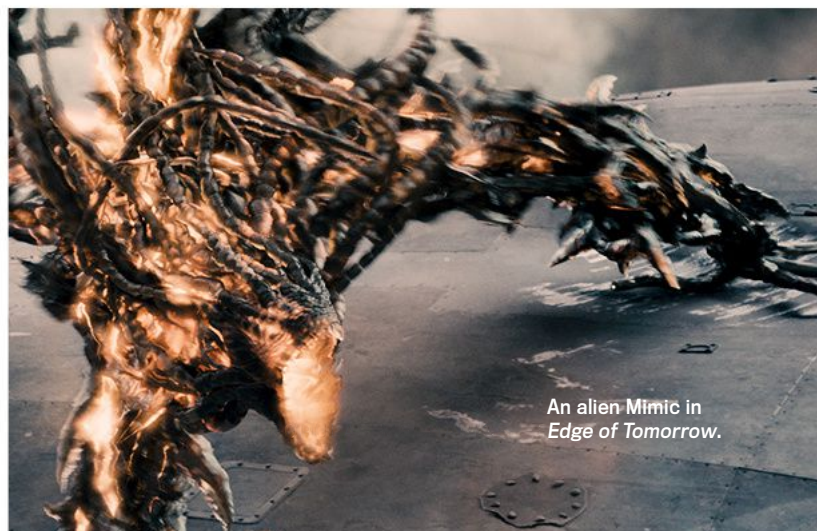


Scarlett Johansson
sheds her human form
in *Under the Skin*.

BEST ALIEN (ALIEN EDITION)

Edge of Tomorrow

Edge of Tomorrow production designer Oliver Scholl and his team started by answering some basic anatomy questions: "Is this going to be humanoid or some 12-legged, tentacled thing?" They considered various incarnations until visual-effects supervisor Nick Davis suggested a different approach. "He said, 'Rather than what it looks like, let's think about how it actually moves and how we're gonna battle it,'" says Scholl. "That gave us this idea that there's no front and back, there's no directional sense in the creature." The result is killing machines. "You just remember them as these dervishes of tentacles that are flying across the beach." ▼



An alien Mimic in
Edge of Tomorrow.

Best Makeup

Foxcatcher

When director Bennett Miller approached Oscar-winning makeup artist Bill Corso to transform Steve Carell into troubled blueblood John du Pont, he had one instruction: "He needs to be a completely different human being." The process involved several steps.



▲
BEFORE



▲
AFTER

2.5 hours in the
makeup chair

1

The Nose

After creating a life cast of Carell's face, Corso made multiple shapes of possible noses out of clay. "Du Pont was known as the Golden Eagle," Corso says, "so I gave him this eagle-like nose."

2

The Skin

The hardest step was altering Carell's complexion. "Steve has a swarthy, Mediterranean skin tone," says Corso, "and du Pont is pale, translucent. Painting Steve's skin took longer in the makeup chair than even putting on all the rubber stuff."

3

The Mouth

Du Pont had a distinct way of holding his mouth and a very soft lower lip," recalls Corso, "and Steve has sharp, perfect lips. When du Pont talked, his lips rounded in a way that's so different from Steve's," so Corso gave Carell a fake lower lip—"almost a whole fake chin"—and added plumpers "to fill the lower part of his face out." Also, the teeth had to be addressed: "Steve has big, white, movie-star teeth, and the real du Pont had tiny little grey teeth—like rat teeth almost, which is surprising for a man of wealth."

4

The Face

Carell's face is narrower than du Pont's, so Corso shaved his hairline to emphasize his forehead. To minimize his eyebrows, a cover was placed over them. "We toyed around with the idea of shaving them off, but Steve was starting *Anchorman 2* right after we finished."

The Shoestring Budget Award

Siddharth

Richie Mehta's *Siddharth* was shot in 21 days with a budget of only \$300,000, which limited him to only a few takes per scene. ("We didn't really have permits," says cinematographer and visual-effects artist Bob Gundu.) So Mehta and his team allowed Delhi's unpredictable hustle and bustle to create atmosphere around the characters. They didn't

use extras, just passersby—and a little creative editing. "There'll be that one take that looks great, but then you look in the background and someone's staring at the camera," notes Gundu. Instead of reshooting, "We would use the head from the previous take and slap it onto this one." In all, Gundu did nearly 50 eye and head replacements. ▼



THE INCREDIBLY SPECIAL EFFECTS AWARDS

How to Make a Boxtroll

1. The faces are attached with magnets. More than 53,000, each with a different pose, were used in the movie.

2. The 9-inch metal-and-silicon puppets are positioned, then a picture is taken. The puppet is moved ever so slightly, then another picture is taken. And so on.

3. Working full-time, each animator created only 4 seconds of film a week.



Achievement in Stop-Motion Animation

The Boxtrolls

Laika animation studio's *The Boxtrolls* used a traditional technology—stop-motion animation—in a highly modern way. Brian McLean, director of rapid prototype, was responsible for creating the faces: “We model and animate them on the computer,” he says, “and then print them on the 3D printer.” ▲

LONGEST PRESUMED TAKE

Birdman



Director Alejandro G. Iñárritu's greatest trick in *Birdman* is creating the impression that the entire movie is one continuous shot. And it's a trick he plans to keep secret. “Part of the difficulty of being an editor is you never talk about the work you actually did,” coeditor Stephen Mirrione explains. “It's a bit of doctor-patient confidentiality.” He and coeditor Douglas Crise will acknowledge that Iñárritu rehearsed with his cast for

weeks before the shoot, filming the sessions so that he could experiment with the best places to make invisible cuts and add imperceptible pauses within the action. For those who welcome frustration, Mirrione offers this tidbit: “In a general sense, some takes are longer than you would believe possible. And some of them have more cuts in them than you could ever see or imagine.”

Best Analog Effect

Boyhood

Richard Linklater's film was shot over 12 years. The characters' aging was the result of time, not makeup.



Actor Ellar Coltrane, first year of filming



Three years in



Twelve years in

Best (Fake) Sex Scenes

Nymphomaniac

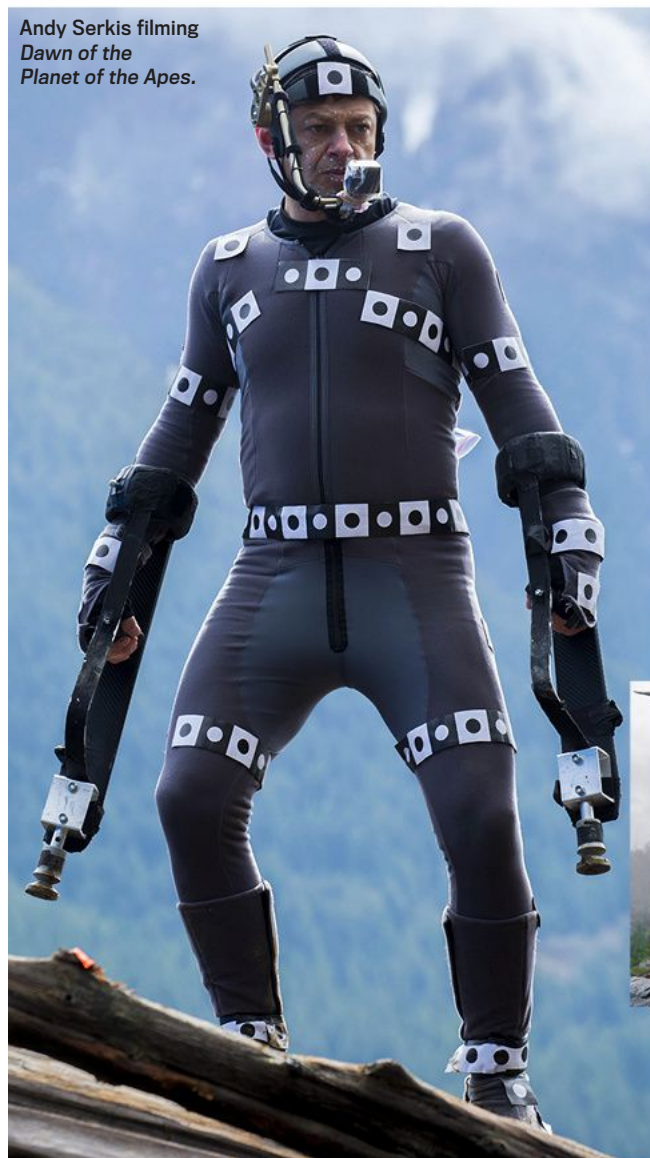
In Lars von Trier's *Nymphomaniac*, Hollywood stars seem to be engaging in explicit on-camera sex. But it was actually a computer-enhanced trick: According to the movie's visual-effects supervisor and second unit director, Peter Hjorth, the actors' movements were combined with that of porn doubles, using a little CGI where necessary. "We had some very basic performance-capture points on the actors' bodies and maybe a witness camera, so we would know the spatial relationship between them. Then I would work with porn doubles to replicate that. We'd shoot that and then we would find the best match, merging them in postproduction."

Most Inventive Prosthesis

Dawn of the Planet of the Apes

▼ Terry Notary, the film's lead ape coordinator, spent six weeks in his garage developing arm extensions to make "quadrupedding" easier for the humans playing apes in the movie—and to make the movement look more realistic on film. The extensions, which are welded from aluminum and have high-performance, pivoting rubber crutch stoppers at the toe, allowed the actors to "jump over things like cars and land on their hands," Notary says. And apparently they're super-easy to get the hang of: "Once you get comfortable you want to be on them all the time."

Andy Serkis filming *Dawn of the Planet of the Apes*.



After a short time wearing the ape arms, "you feel like they're a part of you," Notary says.





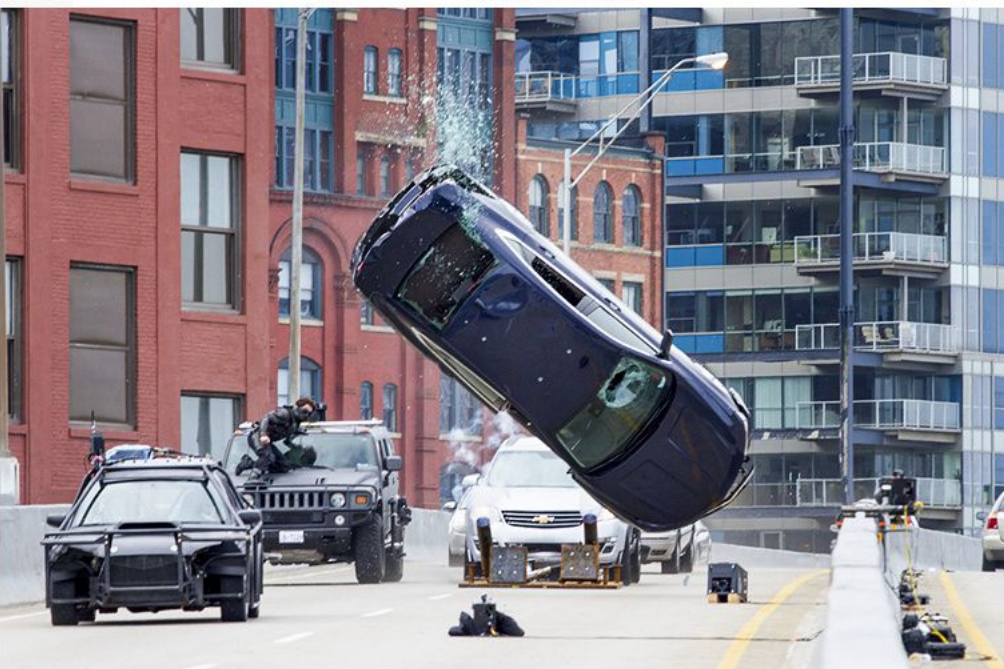
The crew maps out the chase.

BEST ACTION SEQUENCE

Captain America: The Winter Soldier

◀ Spiro Razatos, the film's second unit director and stunt coordinator, explains how Nick Fury's race through downtown D.C. came together: "The directors [Anthony and Joe Russo] had seen a chase in Brazil, a real car chase. This guy went from light traffic, where the cops were chasing at high speeds, to heavy traffic, where he had to work his way in and out and back up into cops and motorcycles. They said, 'We want this thing to start off with some speed and then we want it to get to the point where all hell breaks loose and he doesn't have anywhere to go.' Usually, it's speed or destruction, but in this chase scene it was more about congestion with people and all the chaos. They wanted this to be real.

"The guy getting hit into the bus stop, the guy getting backed into . . . All that stuff, the rehearsal, it takes months. The bus stop is my favorite part. We had that car on a ratchet system, meaning that the car would swing in exactly the same way each time. We started off easier. We put a 3-inch pad across the car, it got pulled in slowly, and the stuntman took the hit. We did that until he got the timing down, and then we took the pad off the car, put the people in there, and put in the real glass."

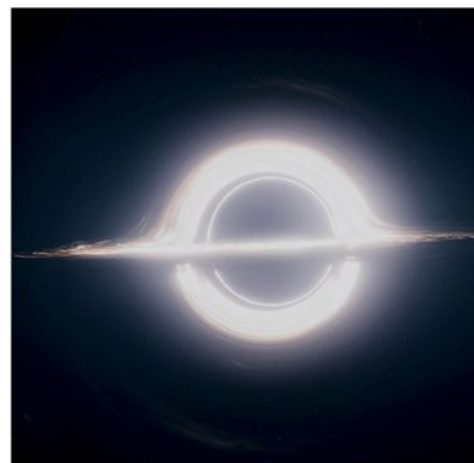


ACHIEVEMENT IN SCIENTIFIC ACCURACY

Interstellar

Theoretical physicist Kip Thorne has consulted on many films, but usually after they've been shot, when producers want someone to validate what's already there. That wasn't the case with Christopher Nolan's *Interstellar*. Thorne met with Nolan and his brother (and cowriter) Jonathan early in the process to discuss possible plot points for scientific validity.

As for one of the major features of the film, the black hole, "we have lots of observations on them," Thorne says. However, "The warp drives and wormholes are speculation. We have no proof that they can occur, but since we can't rule them out, in my view they are acceptable devices for a science-fiction movie." To Thorne's mind, the question of scientific accuracy isn't as important as helping people understand that not all science is the same: "Having a film that includes speculative science, as well as established science, gives me an opportunity to try to convey to a general audience the difference between the two and give them some sense of how—as we collect more data, more observations, more experiments—we may transform speculation into educated guess, into truth." ▶



Visual effects: Postproduction digital manipulation of footage. **Mo-cap:** Short for motion-capture, the process of

Best Green-Screening

Mortdecai

Director David Koepp explains: “The more you mess green-screen images up the better. When we’re moving and the object is moving, our eye is used to seeing things in a blurry, bouncy way.



Shaking or vibrating the camera helps, as does de-focusing and lens flares. In this frame the car wasn’t moving, but others required it to be moving quickly, in which case you need very secure cabling to make sure you don’t send your lead”—in this case Johnny Depp—“bouncing off onto the sidewalk.”

And Now a Few Words From Your Host . . .

Olivia Munn has been charming comedy fans and gadget enthusiasts since she first appeared on *Attack of the Show*, the cult-hit news and technology review on the channel formerly known as G4, in 2006. Since then she’s played a fake journalist on *The Daily Show* and a real journalist on HBO’s *The Newsroom*. She currently stars alongside a very mustachioed Johnny Depp in the action-comedy *Mortdecai* (out January 23), which deserves its own special award (left), even if it didn’t come out in 2014. She sat down with **David Katz** in Los Angeles to discuss.

POPULAR MECHANICS: This is a weird-looking movie.

OLIVIA MUNN: It’s a comedy heist movie. Johnny Depp, who plays Charles Mortdecai, is a British man who’s running out of money and selling off his possessions to keep up his lifestyle. I play a spoiled rich girl who hears about a special painting that could be worth a lot of money, so she goes out to steal it.

PM: Why would she steal it?

OM: Everyone’s trying to get this painting. My character has a very strange mustache fetish, so that can derail things sometimes. There’s definitely a scene with a horse.

PM: So this is slapstick.

OM: Grounded in reality.

PM: I read that you used to build things with your brothers. How many brothers do you have?

OM: Two. My older brother makes motorcycles, and my younger brother is an engineer. He recently went back to school for his master’s in physics.

PM: Is this an affinity that you share? Are you mechanical?

OM: Yeah. My sisters were always doing makeup and curlers, and I wasn’t interested in that. As early as I can remember, when we’d all be kicked outside for the summer, my brothers and I would make a huge fort and string out the electricity from inside and build an air-conditioning unit. In the winter we built igloos. We made them so perfect that we’d be

sweating inside. For fun, occasionally we’d decide to do something like make our own batteries out of pennies. We’d just create.

PM: A battery made out of pennies?

OM: It’s just a battery. You can charge like—we did something that lit up. Obviously it’s easier to go buy a battery, but it was more the idea of it. A *Survivorman* kind of thing.

PM: Since you’re hosting our movie technology awards, I should ask if you’ve done any green-screen work.

OM: The biggest thing I ever did was for G4: “Avatar Thelma & Louise.” In our skit, they actually survive, somewhat, and get turned into avatars. We had to do full blue makeup. I was blue for a long time. Blue in my ears, blue everywhere. You’re probably thinking, wait, wait—why do we have her on the cover? But I did do my own stunts on *Mortdecai*.

PM: What kind of stunts?

OM: I learned how to ride a horse. They told me I had to jump out of a story-and-a-half window. They said, we’ve got a stunt double, but why don’t you just see if you can do it?

PM: Did you like doing that?

OM: I grew up doing karate and gymnastics and everything, so there’s a part of me that likes the challenge. Later I had to ride in on this horse at full gallop through a very narrow path and trees coming up over us and land literally on a dime and jump off the horse.

PM: Good enough for us.





Startup Cities

The best new places to start a business in America.

photograph by DHANRAJ EMANUEL

page 62 ▶



betaversity

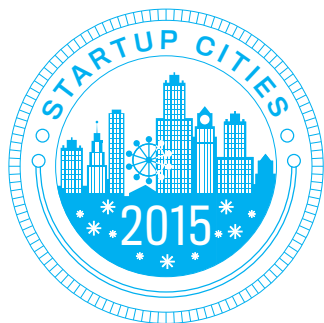
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Sunday, November 16

IDEA
WALL



St. Louis, our No. 1 startup city, is alive with entrepreneurship. Betaversity, which makes these mobile makerspaces that can be set up anywhere, was cofounded by a student at Washington University.



1

ST. LOUIS

MISSOURI

Universities and nonprofits feed a fast-growing startup scene.

INTERSTATE 44 CUTS THROUGH DOWNTOWN ST. LOUIS, FOUR LANES OF ASPHALT,

the city center on one side, the Mississippi River on the other. On a sweltering weekend last July, construction crews shut down the highway where it dips 20 feet below ground level. A massive crane wheeled onto the roadbed. One by one, the crane swung 40 huge girders into place, 100-foot-long steel ribs spanning the highway like fingers reaching out from downtown to the water below. The girders form the foundation of what will be part of a resplendent park.

Cities do this—correct their mistakes. Boston (I-90) and Cincinnati (I-71) and Hartford, Connecticut (I-91), and now Seattle (the Alaskan Way Viaduct) have all decided in recent

years that a traffic-choked interstate slicing like a wound between the city center and the waterfront is not such a good idea after all. They are patching over roadways with parks and plazas that breathe the life of the river or harbor back into a city center. And the effort in St. Louis, which they call CityArchRiver 2015 and which will ultimately cost \$380 million, comes at an opportune time for the city.

St. Louis is a place where people come to make things—always has been. It was founded by enterprising fur traders and thrived on the wealth of railroad barons and beer moguls. Then manufacturing seized up, the recession hit, and Anheuser-freaking-Busch, a symbol of American economic might, sold out to the Belgian company InBev.

Dark times. Nobody moving in. Few people making anything.

But now this park—this bridge over the highway—is a symbol. A sign that construction of all kinds of things has returned, or is returning, or might return. An inspiration.

On a revitalized corner of Washington Avenue, lined with new trees and granite curbs, a shared work space and startup hub called T-Rex has almost finished renovating a landmark 1898 building. The city and its chamber of commerce are behind T-Rex, which now offers 80,000 square feet of office space for fledgling companies. Sample tenant: Betaversity, the brainchild of Washington University biology student Blake Marggraff, 22, and two of his associates. The company's main product is the BetaBox Mobile Prototyping Lab, a work space with 3D printers, laser cutters, CNC routers, and more—all cleverly wedged into a shipping container. "Our company has been around for about 11 months and served 22 clients, which is pretty crazy," says Marggraff. "We've been renting out BetaBoxes up and down the East Coast."

Before moving into T-Rex, Betaversity received \$50,000 from Arch Grants. Founded in 2011, the nonprofit has awarded \$3.1 million to 55 startups, according to executive director Ginger Imster. Arch Grants is one of 15 entities—including Washington University, St. Louis University, and the University of Missouri—St. Louis—that support local entrepreneurship.

It's not unusual today for a city to have a robust support system for startups. But the network in St. Louis came together like lightning. When Anheuser-Busch was sold in 2008, St. Louis's unemployment rate was about 6 percent and rising sharply. (It peaked 15 months later at 10 percent.) That's when a consortium of business leaders, the state economic development agency, the St. Louis chamber of commerce, and the universities devised a



Clockwise from above: Ginger Imster of Arch Grants; T-Rex coworking space; Elaia and Olio, part of a thriving new restaurant scene.



How Did We Come Up With This List?

No disrespect to places like Brooklyn and San Francisco, the early adopters of the startup economy. But we wanted to identify the next wave, cities building an ecosystem—

or revising an existing one—to turn innovators into entrepreneurs. Cities with makerspaces, shared work spaces, business incubators and accelerators, cheap rent, supportive

A HIERARCHY OF POSSIBLE STARTUP-CITY CHARACTERISTICS

APPEALING

Low rent
Available workforce
Educated workforce
Access to venture capital
Temperate climate
Proximity to suppliers
Proximity to Applebee's

UNAPPEALING



plan to create jobs by creating startups. From 2011 to 2013 the ecosystem supporting entrepreneurs more than doubled in size with the launch of eight makerspaces (shops with tools like 3D printers and laser cutters), accelerators (early-stage investors and mentors), and coworking spaces (a shared office for startups, with low rent).

"It's not the biggest scene," Marggraff says. "It is, however, extremely exciting, because it's one of the fastest accelerating. We want to create a maker system that would attract anyone."

The maker system, as Marggraff calls it, is just one thing that makes St. Louis attractive. The city is a patchwork of parks, funky old neighborhoods, and grand stone homes, but now a current of commerce races beneath it. The new business corridor starts at the riverfront and reaches 8 miles west. In two years, when the Gateway Arch park renovation is finished, entrepreneurship, which gave St. Louis its start, will have long since jump-started its rebirth.

elected officials and colleges, great restaurants, and craft breweries. And most importantly, young, fearless strivers who want to define their own future.

Following the Asheville ethos, Farm & Sparrow uses only local grains.



2 ASHEVILLE, NORTH CAROLINA

The craft breweries. The mountains. The new, sustainable businesses.

Mike Rangel, a pioneer of the craft-brewing industry in Asheville, North Carolina, says it's a BYOJ city, as in "bring your own job." People may move here for college or because it's naturally beautiful and reasonably inexpensive. But they stay for the chance to make a living exactly how they want to. The Blue Ridge Parkway dips into a valley and cuts through town as it peels toward the Great Smoky Mountains National Park. As you make your way past the art galleries and restaurants downtown, catching whiffs of pine (and weed), you may wish you could move here, which is what so many entrepreneurs have already done.

Asheville is awash in startup breweries—Wicked Weed (see?), Green Man, and about 20 more. Many are supplied by Riverbend Malt House, which grows and processes local grain. Launched in 2011, it recently secured expansion funding through the Accelerating Appalachia incubator, which backs sustainable agricultural and food startups.

Venture Asheville, a public-private partnership, is the primary business accelerator in town. It's the headquarters of the Asheville Angels, a network of seasoned executives looking to back startups, and the Venture Asheville Mentors, which pairs established entrepreneurs with new ones. Asheville's status as a sweet college town and haven for neo-hippies isn't fading; it's just changing to reflect the influx of people who see no harm in making a little money.



3

OAKLAND

CALIFORNIA

Makers drive the other Bay Area startup boomtown.

TEN YEARS AGO Walter Craven relocated his furniture design and fabrication business, Blank + Cables, from San Francisco to Oakland, which, he says, welcomes “dirty welders and sparks and noise.” In fact, flying sparks and noise have signaled productivity in Oakland ever since the city’s blue-collar workforce built Navy ships there during World War II.

In the early 2000s, before the maker movement had a name, industrial artisans in Oakland opened two high-tech DIY shops,

Nimby and the Crucible, hangar-size work spaces with machinery for creating just about anything. By 2013 the maker community was spawning startups and emerging as an economic force, prompting the launch of Oakland Makers, a manufacturing-industry advocacy group.

Oakland perfectly suits Alec Rivers of Taktia, a startup developing a handheld CNC router. After earning his doctorate from MIT in 2013, Rivers set up Taktia’s West Coast operation in BlueSprout, a business incubator in a



Artist Orion Fredericks works on a sculpture at American Steel Studios.

renovated old brick building with massive windows. Rivers says lower costs drew him to Oakland, where industrial space and apartments rent for 57 percent and 59 percent less, respectively, than they do in San Francisco.

If San Francisco is the nation's tech hub, then Oakland is its makerspace. "We exemplify community compassion: bring everybody along, bring the village along," says Margot Prado, the city's senior economic development specialist. "That's what the maker sensibility is."

The Charlie Noble ^{7.25} Spice brined & roasted turkey breast, brussel sprout slaw, horseradish provolone
 Porchetta ^{7.25} Sausage stuffed pork belly, pickled tomato, arugula, citrus mayo, house focaccia
 Pastrami ^{7.50} "Cuban" Ruben house made Angus pastrami, braised pork, sour kraut, swiss garlic dill
 Schooner Tuna ^{7.50} Olive oil confit tuna, white beans, kalamatas, pickled onions, herbed fennel
 Farmer Ted ^{6.50} Spiced hummus, Vermont goat cheese, olives, cucumber, lettuce, pickled onions



PORTLAND, MAINE

Where the new definition of Yankee ingenuity includes turning your idea into a business.

4

Three square blocks. That's roughly the size of the epicenter of the industrial boom in Portland right now. You'll find them in East Bayside, your classic old-tool-and-dye-factories-turned-coffee-roasters-and-breweries-plus-a-Whole-Foods neighborhood. Bomb Diggity Bakery, Rising Tide Brewing Company, Urban Farm Fermentory—

businesses like these are redefining this historic port-based trade hub as startup central.

In 2011 the city's government and business leaders created a growth plan based on the "creative economy." One result: Last June Portland hosted the first Maine Startup & Create Week, with 100-plus speakers and a series of pitch and networking sessions. Meanwhile, the Center for Entrepreneurship at the University of Southern Maine awards \$25,000 annually to the winner of its small-business-plan competition. The new Casco Bay Technology Hub this year will begin offering early-stage investment in digital startups. Makers and artists can design and prototype their wares at the Open Bench Project, a maker-space with wood and metal shops, and a 3D design and printing studio. And there is beer. Rising Tide launched in 2010 with one employee and now has 11. Indeed, the 13 craft breweries in Portland are important: They create jobs, draw tourists, and give the workers something to drink at night.

Damian Sansonetti (above), former executive chef of New York's Bar Boulud, launched Blue Rooster Food in 2013.



SIGNS YOUR COMMUNAL WORK SPACE IS ACTUALLY JUST A STARBUCKS

- Bells jingle on the door when you enter. ○ Someone actually refills the creamer.
- The conference room has a sign that says MEN. ○ You're not allowed to work past 11. ○ There is a homeless man sitting beside you.



5

BALTIMORE

MARYLAND

A model of post-industrial revival based on innovation (and food).

THE GRAFFITI ON THE WHITE CARGO VAN PARKED in front of Baltimore's Woodberry Kitchen looks like a kid drew it with a blue Sharpie. It shows a cartoonish steak knife with a dot for an eye, a comma for a smile, and a dialog bubble that says, "Cut out the pesticides!"

In 2007 when Spike Gjerde opened Woodberry in a repurposed 19th-century millhouse, he bought his goods from a handful of purveyors at local farmers markets, and had 17 people on the restaurant's payroll. Today he has four restaurants, 270 full-time employees, and more than 225 suppliers, all of them local producers. (The van with the graffiti is from pesticide-free Cottingham Farm in nearby Easton, Maryland.)

"The term farm-to-table didn't exist when we started out," Gjerde says. "But we had a story we wanted to tell, which is about how to be part of a local food system."

Gjerde's insistence on locally sourcing everything he serves has had a ripple effect, generating jobs not only for Baltimore-area farmers but also for fishermen in the Chesapeake Bay, local beekeepers and syrupmakers (honey and maple syrup are two of his primary sweeteners, Maryland not being a sugarcane state), and producers of organic meats and cheeses.

"Local cheese here used to be a joke," he says. "But we supported the cheesemakers as they strove to get better."

Baltimore's startup scene predates Woodberry Kitchen but has grown dramatically in recent years. Under Armour launched here in 1998 with a handful of employees—it now has more than

1,300. In 1999, Emerging Technology Centers opened in the historic Canton neighborhood in the 19th-century brick buildings formerly occupied by a can manufacturer. In 15 years the business incubator and accelerator has aided more than 350 companies that have attracted \$1.6 billion in investments. In the past two years seven more accelerators have opened in Baltimore.

One thing that helps all startups in Baltimore—a low cost of doing business, including reasonable rents—also helped Gjerde. But something harder to quantify gave Gjerde a specific advantage. "Baltimore has always been a little behind-trend," he says. "That gave us the opportunity to nurture the local-food-system idea and grow it. People gave us time to get it right."

At Shoo-fly, Spike Gjerde serves only craft spirits made east of the Mississippi.



HOW TO SUCCEED: INSTRUCTIONS FOR NEW BUSINESSES

1. Pick a good name.
2. Hire no more than two of your friends.
3. In fact, you should hate your accountant.
4. Send free samples/trials to everyone.
5. Invest in a great website.
6. Don't do the podcast you're thinking of.
7. Don't skimp on the Ping-Pong table.
8. Hope to sell to Google.

6

HOLYOKE, MASSACHUSETTS

An enterprising young mayor pushes an old manufacturing and mill town into the 21st century.



BY ALEX MORSE, MAYOR

I was born and raised in Holyoke, and I moved back here right after I got my degree in urban studies. At college I learned about the life cycle of cities, how they can run into bad times but also come back and be successful again. I wanted that for Holyoke, so I ran for mayor and won in 2011, when I was 22. In the three years since, my administration has worked with partners in the community and the region to make Holyoke a center of innovation.

One advantage we have is cheap energy. On the city's east-

ern border the Connecticut River drops 57 feet as it presses south. When the city was founded, in 1850, the river powered waterwheels for paper mills; today it generates inexpensive, clean energy. The old mills are attractive industrial work spaces. A new coworking and makerspace, Brick Coworkshop, has been in one of the old mills since 2013. The owner says his operating costs are about a third of what they would be in a bigger city like Boston.

The Massachusetts Green High Performance Computing Center opened here in November 2012 and has drawn other tech-based businesses to the city. Spinoff development includes Gateway City Arts: We gave them a tax incentive—a first for a local creative business—and they recently purchased another building.

We just launched our Spark initiative with a \$250,000 grant from the Boston Fed to support “entrepreneurship for all.” Sometimes people with good ideas don’t know how to access space or get business permits or financing, so Spark helps out. That fits with my idea that government should take an active role in the development of the future. Some people say it should take a back seat. But a lot of things that happen in this community wouldn’t happen if our team didn’t have the will to make them happen.



OTHER RIDICULOUSLY YOUNG MAYORS

Robert Tufts, 4, Dorset, Minnesota, elected 2012 ◦ **Brian Zimmerman, 11**, Crabb, Texas, elected 1983 ◦ **Kyle Corbin, 18**, Union, Oregon, elected 2006 ◦ **Luke Ravenstahl, 26**, Pittsburgh, Pennsylvania, elected 2006.

7

BOULDER

▼ COLORADO ▼

A top city for startups gets a new push from a university.

Beautiful mountains, rushing rivers, a history of cutting-edge nuclear innovation since 1952—you may know some of the things that make Boulder great but not all of them. Like the nuclear thing: In 1952 the U.S. government planted its nuclear-weapons development program here, creating a demand for University of Colorado-Boulder physicists and engineers to fulfill Department of Defense and NASA contracts. It also led to Ball Aerospace, a 1956 startup cofounded by a CU-Boulder grad student. The small city (big town?) has been a haven for innovators in technology ever since: A 2013 study found that Boulder had six times the national average of high-tech startups. That number stands to grow, thanks to a partnership between CU-Boulder’s new Silicon Flatirons entrepreneurship center and the Atlas Institute, a technology incubator. “Boulder’s startups once operated parallel to the university,” says Brad Bernthal, director of Silicon Flatirons’ startup initiative. “But now CU ‘gets it’ in terms of innovation trends.” It also gets it in terms of grants, having recently landed \$4 million from the Blackstone Charitable Foundation. The mountains are still pretty spectacular too.



8

RENO

NEVADA

Maker HQ for Burning Man. Hotbed for new technology businesses.

Startups need support. They need coffee and alcohol and sometimes even a special flag. Like in downtown Reno, where James Elste moved his year-old startup, Inqiri, in 2013. It's a popular neighborhood, with restaurants, a movie theater, and parks along the Truckee River, and as Elste got to know the area a little better, he found that there were dozens of other recent startups there, clustered around Reno Collective, a technology-focused shared office. But they didn't have a support system. Or even a name, which they remedied within a few months, calling the neighborhood Startup Row and creating banners to hang from light posts. All that was left to solve was the alcohol, so Elste and his partners introduced Whiskey Wednesdays at a local pub to keep the group connected.

Although technology startups like Elste's make up the majority of new businesses in Reno, the city also caters to makers, with an arena-size makerspace and artists' studio called the Generator. Between 75 and 300 fabricators, painters, sculptors, metalworkers, carpenters, and craftspeople head there each day—especially before Burning Man, when the giant studio is used to build installations for the festival.

ALLOW ANYTHING
CONNECTED TO
THE INTERNET
TO MOVE MONEY
QUICKLY, SAFELY, &
AT A COST AS
LOW AS POSSIBLE
DWOLLA

Ben Milne's mobile-payment startup, Dwolla, started with two employees. It now counts the state of Iowa as a client.



9

DES MOINES, IOWA

A Midwestern center of culture and the insurance industry gets behind local entrepreneurs.

LAST OCTOBER AOL COFOUNDER STEVE CASE rolled into Des Moines on his tour bus. The city was one of five one-day stops on his Rise of the Rest Road Trip, during which he looks for startups to invest in. That afternoon he hosted a *Shark Tank*-like competition at the Science Center of Iowa. After hearing nine pitches, Case invested \$100,000 in Bawte, an app that organizes user manuals and warranties. Bawte beat out Igor, which creates software to manage energy use remotely. But just days after Case left town, Igor landed \$2.5 million from private investors and a \$300,000 loan from the Iowa Economic Development Authority.

Money flows into a healthy startup scene. In Des Moines it's healthy because of places like the Iowa State University Research Park, a 400-acre campus in nearby Ames that not only helps new businesses get started but also helps established ones grow. In downtown Des Moines the coworking space Gravitare opened last fall three blocks away from the Des Moines Social Club, an event space, gallery, restaurant, culinary school, and bar in a renovated firehouse. People like living in Des Moines because of places like this, and also because of the city's 550 miles of bike trails.

Yeah, but how do you get there? I mean, Des Moines? Where is Des Moines? Well, here are the flight times from a few cities: New York, 2 hours, 50 minutes. Chicago, 1:15. Dallas, 1:50. Minneapolis, 1:10. Phoenix, 2:50. See, it's not bad.



INDICATIONS YOU'RE NOT YET READY FOR EXPANSION

You don't collect a salary. ◊ Your only clients are your relatives. ◊ You print your own business cards. ◊ Your idea of trademarking your company name is to always write a little TM next to it when sending work emails. ◊ Your professional duties include CEO, CFO, COO, and janitor. ◊ Mom still brings lunch down every day at 12:30.



Furnituremaker
Jason Radcliffe is part
of Cleveland's
improbable revival.

10

CLEVELAND

OHIO

Where scrappy
makers coexist with
medical-tech startups.

Of all the things someone might have suggested Cleveland needs, a new magazine couldn't have been too high on the list. But in 2006 Anne Trubek came to Cleveland and later launched *Belt*, an online magazine and book publisher that covers the Rust Belt revival. She chose the city, in part, for the low cost of living and running a business. She's staying because she loves the place—and the spirit of its people. "We were down for years," Trubek says, "but energy is coming back to the city. Good things are happening, and we know we need to give those good things a push."

Along with the local biomedical and biotechnical industries (and Trubek's work at *Belt*), those pushes are also coming from Cleveland's own little-known maker scene. Six years ago Jason Radcliffe, a local designer and fabricator of metal furniture, organized the first F*SHO furniture show with four other makers. "In one day we drew 350 people," he says. Last year F*SHO exhibited work by 30 craftspeople, and more than 2,500 people attended. "Each year the show brings new buzz," Radcliffe says. "The show has brought success to a number of participants and inspired other people to become makers themselves." Cleveland's resurgence has begun, and for once its prospects have nothing to do with LeBron.



11

URBANA

ILLINOIS

A top engineering university anchors the startup scene.

Sometimes it takes only one institution to fire an entire town's imagination. In the case of Urbana, that institution is the University of Illinois at Urbana-Champaign (UIUC), which graduated the engineering and technological talent that started Netscape, PayPal, Tesla Motors, and YouTube. To this day UIUC incubates and accelerates startups, whether they're run by students or not. "Anyone can request a free consultation with our entrepreneurs-in-residence, or get help with writing grants for funding," says Laura Frerichs, director of UIUC's Research Park. And since the cost of living is only slightly higher than the cost of those free consultations, Urbana is as good a place to grow your business as it is to conceive of it.

Once a department store warehouse, the Falchi Building is the center of the startup culture in Queens.



12

QUEENS, NEW YORK

On the verge of beating Brooklyn at its own game.

YOU KNOW BROOKLYN: flannel shirts, skinny jeans, nonprescription glasses. But what you may not know is that it casts an undeserved shadow over its neighbor: the next great center of innovation in New York City, the borough of Queens. First off, rents are cheaper in Queens than in Brooklyn. At QNS Collective, a coworking space that opened in the neighborhood of Astoria in 2013, you get a desk, locking storage, photocopying privileges, and a generous supply of paper clips, all for under \$300 a month. Two miles away, in Long Island City, you'll find the recently renovated Falchi Building. The former warehouse for a Manhattan department store, the five-floor, 650,000-square-foot building houses new businesses such as Lyft (a competitor to Uber) and Coalition for Queens, a nonprofit that supports local technology startups. Plus, Manhattan's renowned Doughnut Plant recently relocated there on a 10-year lease, so at least you won't go hungry.

+ BAD ADVICE

Investors are most interested in comfortable furniture. ○ That's what expense accounts are for. ○ This is a family-run company, right? Then you deal in hugs, not handshakes. ○ Buy 1, get 3 free. Who wouldn't be drawn to that? ○ If you wait to sell your app to Google, it'll always be worth more.



INVENTIONARIES

EVERY GREAT IDEA
HAS A STARTING POINT

There is a moment when imagination transforms to invention. Crossing that threshold requires purpose and a pioneering vision. After all, being first isn't easy—but it's exhilarating. Just ask eco-friendly inventors Anna Stork and Andrea Sreshta.

THEIR MOMENT OF INVENTION

WHEN:
January 2010

WHERE:
Columbia University, NYC

WHAT:
Solar-powered inflatables

TWO YEARS AGO, ARCHITECTURE STUDENTS ANNA AND ANDREA FOUNDED LUMINAID AND CREATED THE FIRST PACK-FLAT, INFLATABLE-DIFFUSED RENEWABLE LIGHT SOURCE.

It's no surprise given their predisposition for prototyping and thinking big. Anna even admits she's always been this way: "I wanted to be an astronomer as a kid. I even built a telescope by hand." Now the duo is the inventor on two utility patents and recipient of the 2014 Toyota Mothers of Invention award.

From the start, they've been in uncharted territory. Their inspiration for LuminAID hit during the 2010 Haiti earthquake. Organizations were distributing other aid but not reliable renewable light, critical for safety and comfort during disaster relief operations. Anna and Andrea decided to address this unmet need. Because of this, they were able to distribute 20,000 LuminAID solar

lights after the 2013 Philippines typhoon and launch an online platform selling nonemergency inflatables with a charitable 1-for-1 component.

LuminAID—part of the skyrocketing alternative-energy movement—is experiencing tremendous growth. "Solar energy is gaining a lot of traction. It's getting smaller and more efficient and we're excited to continue innovating with this technology," says Andrea. Sometimes change happens fast. Just 14 years ago, the Toyota Prius changed the world as the hybrid that started it all. "I think 14 years from now, we'll see solar-powered sources having a bigger impact worldwide," says Anna.

Toyota Prius proudly profiles this generation of innovators. Visit PopularMechanics.com/Inventionaries as we reveal what inspires them.



Let's
Go
Places



13

DETROIT

Bankruptcy, blah, blah, blah. The Motor City has become a place where artists, makers, and technologists yearn to start anew.

A FULL-SERVICE PHOTO STUDIO (WOODWARD AVENUE PHOTOGRAPHY), a residential exterior- and interior-design firm (Brush Park Studio), an artist collective that rents space to painters and sculptors (Corktown Studios), a job placement and training center for homeless women (the Empowerment Plan), a bike advocacy group (Detroit Bike City). They're all alumni of the Detroit Creative Corridor Center's Creative Ventures Residency Program, which puts design- and creative-based businesses through a six-month schooling in scaling their companies, raising funds, and developing client bases with mentors. The artists of Detroit are lifting each other up, and lifting up the city in the process.



INDUSTRIES IN DIRE NEED OF DISRUPTION

Commercial air travel • Congress • Gym memberships • Taxidermy • Delaware

14

AUSTIN

▼ TEXAS ▼

The capital city's top 10 startup virtues, from a local believer.

- 1 Like other startups, my company, the Zebra*, offers great perks. Free home maid service, open bar, bimonthly company outings (karaoke, floating the Guadalupe River), and bring-your-dog-to-work day every day.
- 2 Computer geeks galore. They flow out of UT-Austin and local coding schools and programming bootcamps like MakerSquare.
- 3 We don't have to buy plane tickets to get to SXSW Interactive. Incredible networking and party opportunities every year—free.
- 4 Incubators and shared work spaces. Capital Factory has about 700 members. Pay \$200 a month and you've got yourself an office. The national accelerator Techstars opened here in 2013. It's helped start more than 400 businesses nationwide.
- 5 It's about the people, right? The Zebra is in a building called Chicon Collective with other bootstrappers, the warriors of the startup world. I am proud to be one.
- 6 Not into bootstrapping? Investors like Silverton Partners and Austin Ventures are here to help.
- 7 Weather so nice you wonder why you ever owned a coat.
- 8 A startup scene that does good. The Austin Startup Games is all about this—friendly Texans making the world a better place.
- 9 Google Fiber. Faster Internet is very good for startups.
- 10 Tacos. Breakfast tacos, BBQ tacos, all the tacos. Cheap, cheerful food is also good for startups. — JAIME NETZER

*Sort of a kayak.com for car insurance.



There is a moment when imagination transforms to invention. Crossing that threshold requires purpose and a pioneering vision. After all, being first isn't easy—but it's exhilarating. Just ask inventors Grant Delgatty and Simon Isaacs.

GRANT'S MOMENT OF INVENTION

WHEN:
2013

WHERE:
Art Center - Pasadena, CA

WHAT:
Super-compact e-vehicle

SIMON'S MOMENT OF INVENTION

WHEN:
2012

WHERE:
Library - Brooklyn, NY

WHAT:
Men's parenting resource

INVENTIONARIES

EVERY GREAT IDEA
HAS A STARTING POINT

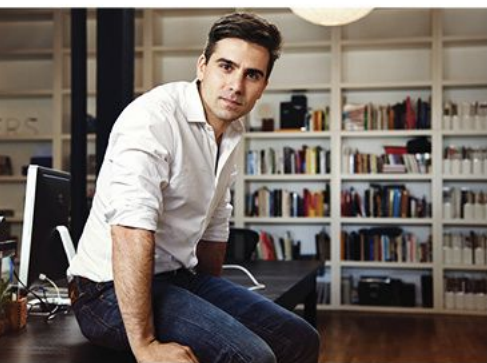
A GEARHEAD IN L.A. AND A FATHER-TO-BE IN NYC ARE ABOUT TO CHANGE EVERYTHING.

Paradigm shifts are underway. Grant Delgatty—cofounder of the URB-E e-vehicle—and Simon Isaacs—cofounder of the men's parenting site Fatherly—agree. Though they inhabit different spheres, both inventors noticed millennials tuning in to social and environmental issues. This insight triggered their breakthrough inventions.

Grant wagered on the growth of clean energy transportation. His super-compact electric scooter solves a global problem: getting that last mile from your car's parking space to your destination. "The URB-E fits between your legs and has the same footprint as your body," he explains. It's the first foldable e-vehicle—with the comforts of a bicycle—that goes up to 20 miles on one charge. Therefore, it's no surprise that URB-E won the 2014 CES Verge

Award. "It's about social impact. Every decision we make needs to be the right decision to protect our environment for tomorrow," says Delgatty.

Simon tapped another emerging market: stay-at-home dads. As the first parenting site focused on men, Fatherly has already doubled its subscribers since launch. "It's a brave new world when it comes to parenting and work/life balance," says Simon. "Being a father ignites a new relationship you have with the world. Dads ask themselves, 'What is the legacy we'll leave our children?'" Just 14 years ago, the Toyota Prius changed the world as the hybrid that started it all. Over the next 14, Grant and Simon agree that socially conscious businesses will continue to win with the next generation.



Toyota Prius proudly profiles a new generation of innovators. Visit PopularMechanics.com/Inventionaries as we reveal what inspires them.



Let's
Go
Places

THE THREAT REPORT

OUR RATIONAL GUIDE TO AN
IRRATIONAL WORLD—FEATURING
A HARD LOOK AT AMERICA'S
VULNERABILITIES (AND DEFENSES),
A REVEALING VISIT TO THE DARK WEB,
AND A DISPATCH FROM
THE FRONT LINES OF THE
NEW COLD WAR.

PART 1



THE LINE IN THE

POPULAR MECHANICS
February 2015



The E-3A features the heft of an airliner and the utility of a Swiss Army Knife—and serves as a symbol of NATO's protective mission.

<



I CLOSE

my eyes and relax into the drone of the engines and the heavy rush of air, I might almost forget that I'm in a military airplane. The NATO E-3A is 153 feet long and built on the same frame as a Boeing 707 airliner, so in contrast to the fighter jets looping through the sky not far away, it is not designed to make any sudden moves. The E-3A is a whale floating along at 35,000 feet, and I am buckled into its belly.

There are few windows. I am sitting at a console with square, lighted switches—one of a bank of consoles lined up three across against the starboard side of the plane. Men in pressed NATO uniforms with patches from their home countries scrutinize every blip, swirl, and ping emanating from the equipment. The aesthetic is vintage 1970s Air Force—all exposed wires and monochromatic colors and seats bolted to the floor, a triumph of utilitarianism. A yellow-and-black-striped handle juts from a bulkhead, a white grate on the floor below. A sign reads: BAIL OUT CHUTE, AIR USE ONLY. It's defunct, but no one lingers on that spot.

The sun is still low after our 7:15 a.m. departure. I'm here because I was issued a rare invitation to shadow a NATO crew on a 7½-hour surveillance mission over Poland. The E-3A is also known as an Airborne Warning and Control System (AWACS) aircraft, and this flight is part of NATO's recently rejuvenated effort to monitor and discourage Russia's military activities, and to reassure the Poles that its allies will be there to quell any aggressive moves by Vladimir

Lately, Russia has been threatening its neighbors almost weekly in what appears to be a Soviet-era show of force. But the rest of the world is not taking Vladimir Putin's imperialist spasms lightly. Popular Mechanics was invited on an official surveillance flight high above Europe as a NATO crew watched for his next move.

BY JOE PAPPALARDO

SKY

Putin should the Russian leader continue to try to rewind Europe back to the late 1970s. Relations in this part of the world have been tense since last spring, when Russia annexed Crimea and helped prop up separatists in eastern Ukraine. Older people in Eastern Europe have seen such developments before—a superpower suddenly snatching away some or all of a sovereign nation—and they often end in violent repression or war, or both. Poland, whose borders touch both Russia and Ukraine, has been overrun by hostile neighbors more times than people there care to count, and many Poles told me they feel distrustful of Putin's sudden latter-day Stalin imitation.

The tension from the shooting on the ground—Russian-backed separatists and soldiers exchanging fire with Ukrainian troops—extends up to this cabin. Just before our mid-September flight, Russian fighter-bombers violated Swedish airspace, buzzed a Canadian military ship in the Black Sea, and encroached on Alaskan airspace. In the months after, a NATO radar team will detect and track a Russian intelligence-collection aircraft that will enter NATO airspace over Estonia. In three days in late October, NATO will detect and monitor four groups of Russian aircraft conducting “a major air exercise” in international airspace, according to the alliance. By late November the Russians will be on pace in 2014 to more than triple the previous year's military aircraft exercises.

“What bothers me most is the offensive nature of what they are doing,” Lt. Col. Ireneusz “Palm” Nowak, the base commander at Łask Air Base in Poland, says. “They are seeking new influence, new land. The activity we observe is of a very aggressive nature.”

Well, then. This should be an interesting ride.



The crew—from left, pilot Olivier Gilson of Belgium, flight engineer Amodio Iaderosa of Italy, and aircraft commander Massimo Maieron of Italy—all speak a technology-heavy version of English on the flight.

T

HE CREW MEMBERS are wearing headsets to block out the constant whoosh of air outside the fuselage, and so they can pass information around the plane and to other aircraft. I put a headset on and am immediately plugged in to a half-dozen technical conversations erupting at once—a drumbeat of acronyms, jargon, and coordinates spoken in English but that sounds like another language altogether. E-3A crews pride themselves on being able to tease out the information they need from this blizzard of chatter.

Some of the crew are conducting surveillance operations on the consoles. A 30-foot-diameter radar sits atop the E-3A, scanning the sky above Poland and over into a slice above Ukraine, watching for Russian aerial incursions like the recent one in Sweden. The radar antenna, spinning inside a disc-shaped housing mounted on the plane's back, can

change the strength and shape of its pulses to spot low-flying aircraft at more than 215 miles, or high fliers at twice that range. At other stations on the plane, NATO personnel monitor radio transmissions and radar waves that can identify targets for warplane pilots and ground commanders if a shooting war breaks out below.

On one headset Capt. Matteo Tani of the Italian air force directs two fully armed Polish air force F-16s. His job is to ensure, from 78 nautical miles away, that the fighter jets stay in their designated airspace, away from civilian planes passing overhead.

“Turn left, descend to flight level 2-1-0, heading 1-3-0,” Tani says in thickly accented English. A voice with an equally heavy accent, this one of the Polish pilot, acknowledges the guidance. The Poles spend an hour performing mock interceptions, taking turns playing the foe, which in this



A SEASON OF HOSTILITY

Russia's military encroached on or entered NATO territory 20 times during 67 unusually hectic days last fall. Together with incidents earlier in 2014, they "add up to a highly disturbing picture of violations of national airspace . . . and other dangerous actions happening on a regular basis," a NATO report from November said.



Not pictured:

Russian strategic bombers in the Labrador Sea near Canada practiced cruise missile strikes on the U.S.



TYPE OF INCIDENT

- Air
- Maritime
- Ground

RISK LEVEL, AS RANKED AND DEFINED BY NATO

- High:** Elevated risk of casualties or military confrontation between Russia and the West.
- Serious:** Aggressive or unusually provocative encounters.
- Near-routine:** Not unusual, but the greater frequency is worrisome.

THE AUTHOR'S FLIGHT: SEPTEMBER 13, 2014

Reported incidents between September 1 and November 6, 2014; Source: NATO

scenario is a Russian MiG-29. The radio crackles with F-16 pilots reporting details about the mock enemy's weapons. "The Poles like to get creative," 1st Lt. Bram Wieser, of the Netherlands, says from his AWACS console.

Sitting at an unused E-3A console, I scroll the tactical screen to examine Kaliningrad, the nearest Russian territory on our path. The isolated spit of land, home to Putin's Baltic Fleet, is sandwiched between Poland and Lithuania and contains Russia's only ice-free European port. The air looks empty of military aircraft, but Russian bases are marked with red icons, the designation for hostile. The crew "sanitized" the images on this console before I sat down—this is a real, full-on strategic NATO military operation, not a public-relations flight—so the multicolor webs that represent the radar emissions from Kaliningrad don't appear. But I know they're out there; I've glimpsed sheets marked "NATO—Secret" that display the locations and ranges of Russia's Kaliningrad radar sites.

Military surveillance, after all, goes both ways. I ask Wieser if Russian radar and emissions specialists are scrutinizing us as well. "No doubt about it," he says with a tight grin. "They are playing the same game that we are."

This show of resolve is at least partly political theater. Without the contributions of the United States—itsself looking at tightening defense budgets and embroiled in several global crises—there is no real deterrence in Europe. NATO owns only 17 AWACS aircraft; fighters, aerial refueling tankers, and transport airplanes must be begged and borrowed from member countries. And there is not a lot of metal to go around.

A scant handful of NATO partners, the backbone of the deterrent effort, have defense budgets of more than 2 percent of their gross domestic product. Economic ties to Russia and an abiding mistrust of U.S. foreign policy sap many allied nations' political willpower to stand up to Putin. And for all the talk of bolstering the presence of NATO in Eastern Europe, the vast majority of the equipment stationed there is being used to conduct unarmed training missions.

Back on the screen, the F-16 icons wheel and dart in a mock dog-fight. One pilot locks his weapons radar on his foe; a golden dotted line appears between the icons of the two aircraft. It's an oddly clinical view of an encounter that could, if this were real, represent the start of a new world war.

OUR FLIGHT took off a few hours ago from Ørland Air Station, a small NATO base near the town of Brekstad, Norway, and followed a route that calls to mind some of the flash points of modern European history. Norway endured a Nazi invasion in 1940, and these days the Norwegians fret about Russia's designs on the resource-rich Arctic. The AWACS has permission to fly over Sweden, but the crew conducted no radar surveillance. Instead they primed the equipment as we headed over the neutral country while those without tasks ate sandwiches or heated food in the galley ovens.

Once we reach Poland, the E-3A becomes "on station." At one console in the rear, Staff Sgt. Nick Grafton sits before a trio of screens, each displaying pulsing graphics, oscilloscope waves, and jagged, spiked circles. Grafton is a radar tech trained to divine meaning from the scribbles and patterns.

Most of what he does is classified but too hard to explain anyway. "I've been working with this system for about 10 years," Grafton says. "And there are still things it does that I've never seen before." He teaches me a couple tricks, though. The screen to the far left, with a circular display, measures the strength of inbound signals affecting the circular radar. Each spike represents a power source, and Grafton's job—one of them—is to determine if these surges will affect the radar's main antenna. Jagged spikes from a specific direction could mean the E-3A is being intentionally jammed. Fortunately, the plane is equipped to overpower most interference, he says.

Each crew station solves a puzzle piece of what's going on. The radar operators can spot aircraft flying low to the ground. The passive-detection equipment can help identify that it's a warplane by the signals it's emitting, or by what it's failing to transmit. (Civilian



With the E-3A back on the ground in Norway, 1st Lt. Bram Wieser, foreground, and Master Sgt. Angel Garcia lead the way to the debriefing meeting that wraps up every mission.

^

airliners "squawk" over certain frequencies, making them easy to identify.) The radar operator can ask the pilot to level out the airplane, decreasing the ground clutter from the radar returns by changing the angle of the radiating waves, thereby gaining a better image. It's team sleuth work.

The E-3A can also spot vessels on the water. A Toughbook laptop is set up near one console bank, close to where the surveillance section sits. Its screen shows commercially available ship-tracking data (using the automatic identification system, or AIS). If a radar return doesn't match the AIS data, the airplane may have uncovered a military ship sneaking around, or a smuggler on a run. If the emissions experts and radar techs see abnormally high activity, there's a good chance it's a military vessel. The information is sent to NATO bases in Germany for analysis.

It's not as easy as looking at an infrared video or a satellite feed, but this AWACS has 120,450 square miles in its field of view, so it has to have different sets of eyes that work in complex ways. Data streams in from across the electromagnetic spectrum. "We have the God's-eye view," says Sgt. John Brewer, a U.S. weapons-section operator on board.

Fighter pilots on the ground in Poland stand on alert—the official phrase is quick reaction alert, or QRA—ready to dash to warplanes if they or an AWACS detect Russian aircraft. Even when the Russians keep to their airspace, the Poles scramble fighters to shadow them when they near the border, just so they know they're being watched.

At Poland's Łask base, where the QRA flights originate, Nowak tells me the Russian aircraft cruise the Polish border on what professionals call recon missions—reconnaissance to probe the readiness and defenses

LT. COL. NOWAK KNOWS THE POLES WOULD BE OUTGUNNED IF THEY FACED RUSSIA IN COMBAT. "WE HAVE TO CATCH UP WITH THEM. THERE'S NO OTHER WAY."

of the NATO crews. "They test the time of reactions, radio freqs [frequencies], how our jets move," he says. "Most of the time we accompany them along the Polish border, then pass them off to another nation's QRA."

The Poles have recruited the United States and other allies to boost their air force. But Nowak knows the Poles would be outnumbered and outgunned if they faced Russia in combat. Most of their air force still uses Soviet-era aircraft that would fare

THE TECHNOLOGY OF TERRORISM

Trying to protect the United States from violent extremists requires creativity, hard work, and technological expertise. They build a new bomb, we try to keep it off planes. They hack our cyber infrastructure, we lock them out. Here, a few of the most recent developments on both sides.

BY P. W. SINGER, JEFFREY LIN, JOE PAPPALARDO, KELSEY D. ATHERTON, AND JACQUELINE DETWILER

poorly against new Russian warplanes and mobile surface-to-air missiles. “We see Russian equipment getting better and better, and we have to catch up with them,” he says. “There’s no other way.”

The crew in the AWACS cockpit is wrapping up the mission. Down on earth, the magnificent desolation of Norway stretches to the horizon. Lichen grows on every rock on the coast, and the ground is a green-brown carpet broken by humps of smooth, weathered mountains. As the E-3A begins its final approach back to the NATO base, the aircraft commander, Maj. Massimo Maieron, keeps an eye on the man to his left. Olivier Gilson, a Belgian first lieutenant, is in training, and he’s the guy landing the plane.

Soon the alien terrain gives way to civilization: a lighthouse, a farm, a road, then the glowing crosses marking the Ørland runway. The E-3A barely jostles as Gilson eases it down. This was a relatively short trip—some missions extend, courtesy of aerial refueling, for more than 12 hours. Maieron’s longest mission was 16 hours circling over Afghanistan.

From the sky the Afghanistan mission was largely the same, he says. It was on the ground that things felt different. “When we land here,” Maieron says, “we don’t have to wear flak jackets.” He and Gilson, after shutting down the aircraft and discussing the landing, are the last crew off. They step down onto the tarmac, flight bags in hand. They’re both eager to shed their flightsuits, but the debrief awaits, and the rest of the crew is already inside. Maieron and Gilson stride toward the looming E-3A hangar, two small green figures before white doors the size of Jumbotron screens. Eight hours after taking off, the pair walk into the towering crack between the hangar doors and vanish inside. Soon, another crew will take off for the same mission, and another crew after that, and then another, until nobody needs to watch Vladimir Putin and his army anymore. ■



IN THE AIR

THE LAND-BASED AIRPLANE BOMB

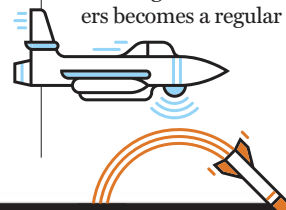
USED BY: THEM

WAR AND REVOLUTION IN the Middle East have opened military arsenals in Libya and Iraq to extremists and black markets. This is not good no matter what the bad guys buy, but it’s especially dangerous if terrorists get their hands on shoulder-fired antiaircraft missiles. Though many international flights avoid taking paths over known conflict areas where they might be at risk even at 35,000 feet, shoulder-fired missiles are portable and could be smuggled near enough to an international airport to do serious damage to planes during takeoff and landing. Missiles like the heat-seeking Russian Igla, which are already in Iraq, can fire up to 11,000 feet in the air along a 2-mile-long corridor, making most airports viable targets.

THE PLANE-MOUNTED MISSILE BLINDER

USED BY: US

SYSTEMS THAT CAN PROTECT airplanes from missiles do exist. Some U.S. military transport planes are already equipped with Directional Infrared Countermeasures (DIRCM) pods that can blind incoming missiles. A 550-pound pod mounted under the fuselage uses a laser to beam infrared energy into the missile’s heatseeker, overwhelming the sensor and causing the missile to lose its target. In the last decade two defense manufacturers, BAE Systems and Northrop Grumman, made prototypes for civilian airliners. But they were too expensive to employ widely. The only way the airlines will ever consider them a good return on investment is if shooting down civilian airliners becomes a regular threat.



ILLUSTRATIONS BY TIM BOELAARS

COULD A TERRORIST ATTACK THE SUPERBOWL? "I don't think [ISIS] would, because it wouldn't be best for them in the long run. Sometimes the insider threat trumps that. Two years ago [a 9/11 truther] got in and got onstage at the press conference after the game. He was able to gain access just by saying he was late for his shift." — JAMES A. MCGEE, FOUNDER OF PHASE LINE GREEN SECURITY CONSULTANTS

IN THE AIR



THE OLD EXPLODING CLOTHES TRICK

USED BY: **US** **THEM**

THIS IS HOW IT GOES:

Terrorists try to smuggle liquid explosives onto planes in bottles, so the Transportation Security Administration limits travelers to 3.4 ounces of liquid per person, an insufficient quantity to bring down a plane. In response, terrorists try to find a new smuggling method. Anonymous senior U.S. security officials recently alerted reporters that some groups have researched dipping clothes in liquid explosives, such as acetone peroxide, that are not detectable by dogs or any routine TSA security scan, letting them dry, and wearing them on flights. So, hey, that's not great. But there is some good news: First, only a couple of ounces of explosives can be infused into clothing. That's enough to hurt people, but not enough to bring down an airplane. Second, a Montreal-based company, Genia Photonics, is testing a laser-based molecular scanner that could pick up chemical traces without requiring airplane passengers to strip in the TSA line.



A Few Questions for
Former Department
of Homeland Security
Secretary

Janet Napolitano

PM: In your farewell speech to the DHS, you warned about cyberattacks. We tend

to spend most of our time worrying about bombs and kidnappings. Are we leaving the back door unprotected?

Napolitano: I think, as a country, we have a long way to go in terms of protection against cyberattack, in part because the whole field changes so rapidly. But this was a constant message we were giving to Congress and industry and

the public. If we were asked, What are the areas of greatest vulnerability? I think we would all put cyber right at the top of the list.

— **Are groups like ISIS capable of these kinds of attacks, or are you more concerned about homegrown groups?**

I don't want to tie it specifically to ISIS and al-Qaida, but I will

say that the attacks come from a variety of sources. Everything from individual hackers, which I might not even characterize as an attack—sometimes people experiment to see how far they can get into a system—to attacks that we can actually attribute to a nation-state. And everything in between. Does that include groups that have a nefarious purpose? The

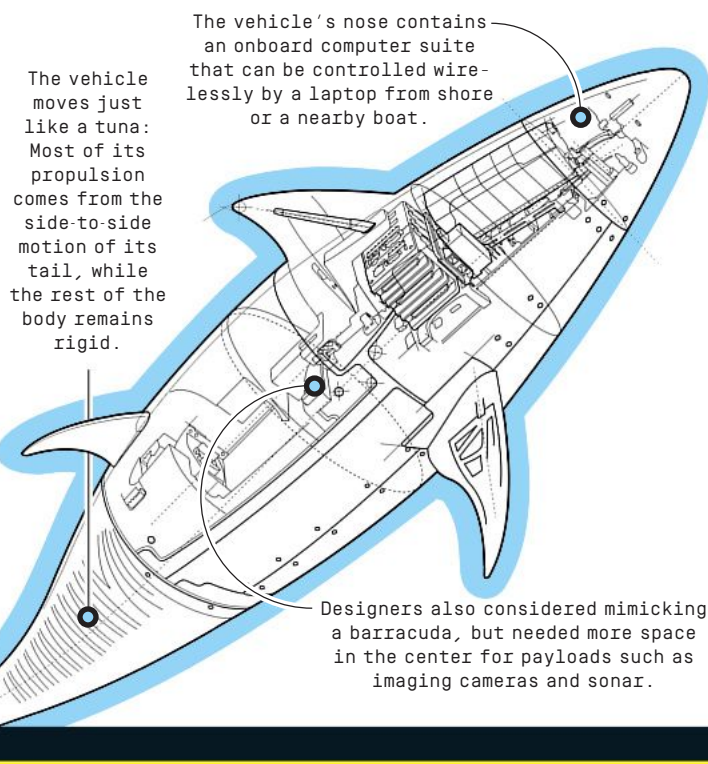


AT SEA

A GARRISON OF ROBOT FISH

USED BY: **US**

TO PATCH THE HOLES in our notoriously leaky port defenses, Boston Engineering Corporation and the DHS have developed an autonomous underwater inspection device based on . . . the tuna fish. It is more agile than other underwater robots and can search for mines or improvised explosive devices in flooded ships and other areas that are too dangerous for human divers. Here's how it works.

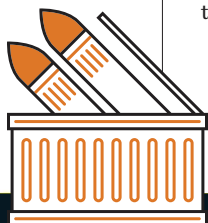


ARE OUR EMBASSIES SAFE? “Ultimately, protection of embassies is the responsibility of the host country, but the U.S. does take an active posture to protect its installations. Considerable security forces, reinforced perimeters, secure locations within embassies, and military and State Department reinforcements are all part of a system to deter, stop, or at least slow down attacks by all but a large, well-armed, and well-trained paramilitary force.” – **JAMES JEFFREY**, THE WASHINGTON INSTITUTE, FORMER U.S. AMBASSADOR TO IRAQ

THE TRANSFORMING CARGO CONTAINER

USED BY: **THEM**

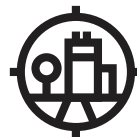
YOU CAN SEE THE SCENE from a military thriller: A cargo ship is sailing along with a normal container on its deck. Suddenly the container tilts upright, the lid flips open, and out pops a cruise missile that blasts into a nearby American port city, causing panic and destruction. It’s all very *Homeland*. Except it’s real. In 2012 Russian defense company Concern Morinformsystem-Agat JSC began testing this system as a last-resort defensive weapon, a martial ace in the hole that could remain hidden during a bombing campaign by a foreign power and emerge to strike back. CGI marketing videos show the missile being used to repel U.S.-style aircraft carriers, but if it fell into the wrong hands, in the same way a certain Russian-made anti-aircraft missile that allegedly shot down Malaysia Airlines Flight 17 last summer did, we could be in trouble.



THE IMITATION SMUGGLING SUB

USED BY: **US**

NARCO SUBS, CLANDESTINE underwater vessels that South American cartels often use to transport drugs between countries, are one way terrorists could smuggle weapons into the U.S. These vessels skim along just beneath the waves and are relatively hidden from radar. Some remote sensing technologies, such as airborne radar, might find them, but these technologies need to be consistently and thoroughly tested in order to pull it off. This is why the Department of Homeland Security (DHS) built its own homemade submersible, a 45-foot, three- to four-person watercraft called PLUTO, in 2008. Its handlers at Eglin Air Force Base near Ft. Walton Beach, Florida, have used the sub to test such technologies as P3 radar systems in Navy aircraft and Customs and Border Protection’s Dash 8 planes. PLUTO is still making test runs today, but the government is keeping quiet about the latest detection techniques.



ON LAND

ETSY FOR TERRORISTS

USED BY: **THEM**

THE AVAILABILITY OF Internet instructions and the proliferation of small but capable means of production are a godsend to inventors and makers. This, unfortunately, includes inventors and makers with nefarious intentions. A guy with a grudge and access to a biology lab could, theoretically, print smallpox DNA from a recipe for the smallpox genome that’s available online, and use suitcase-size microreactors—machines that speed up chemical production—to create enough toxins to spread in a public space. And thanks to new Internet databases, bioterrorists can find quick hacks to maximize production and lethality. If they’d rather launch a chemical attack, there are now better microscopes and computational software that can be used to build tens of thousands of new compounds.

answer, I would say, is yes.

Are there specific steps we could be taking to be more prepared?

I think a lot of this has been left in the hands of the private sector, to increase their investment in—and the care taken with—cyberattack prevention. I think many companies are very, very good, but many, because

there’s not an immediate return on investment for this sort of thing, are more vulnerable. In an interconnected world, a vulnerability someplace can lead to cascading implications.

In some respects, it seems private industry would be more agile than the government at that kind of thing. Oh yes. I think that that can

happen. It’s easy for government to kind of retreat into a . . . how do I want to say it . . . relaxed pace.

Now that you’re the president of the University of California system, do you ever miss the excitement of working in national security? I miss having my own plane. That was good. You know, I

enjoyed my time as the secretary. It was a privilege to serve there, but I don’t have time to reminisce too much.

Flying commercial is tough. Does the TSA make you take your shoes off? No, I have PreCheck. Which you should get, too, if you haven’t already. It’s great. Saves a ton of time.

THE THREAT REPORT

WHAT ARE WE REALLY AFRAID OF?

Man-made disasters we're most worried will occur in the next 25 years, according to the Chapman University Survey on American Fears.

LESS ARE SCARED MORE ARE SCARED

Nuclear/
Biological Attack Economic
Collapse U.S.
Decline World
War Terrorist
Attack

ON LAND



THE PHYSICAL ONLINE ATTACK

USED BY: **US** **THEM**

IN 2009 A WORM CALLED Stuxnet, developed by the U.S. and Israel, devastated an Iranian nuclear laboratory by increasing the pressure in its centrifuges until they spun out of control. The good guys used a computer virus to cause kinetic, physical effects on actual electrical equipment. This is an enormous achievement. But the U.S. has vulnerabilities of its own in this respect. Our power grid is increasingly linked to networks of computer-controlled equipment—the type that runs smart-meter technology, for example—that are open to hacking. This could allow our enemies to destroy machinery such as substation current transformers and power-plant turbines. One way such an attack might play out was the 2007 Aurora Generator Test by the DHS at the Idaho National Laboratory. Hired hackers caused the circuit breakers of one particular generator to rapidly open and close out of phase with the rest of the grid, causing the machinery to explode.

THE NEW SUBWAY CANARIES

USED BY: **US**

IN 1995 JAPANESE CULT Aum Shinrikyo attacked the Tokyo subway, releasing sarin gas and killing 13 people. The story is a grim reminder of transit-system vulnerability, but there is hope for future safety: The DHS has developed two programs to detect these kinds of agents underground. The first, the Autonomous Rapid Facility Chemical Agent Monitor, uses an ion-mobility spectrometer to search for trace chemical vapors such as sarin.

The second, Detect to Protect (D2P), finds biological material in the air, then does lab-quality analysis in half an hour to determine whether it has found an attack or something less sinister. D2P has already been tested with an inert agent in Boston's transit system and could be deployed this year.



PREDICTIVE BOMB DETECTION

USED BY: **US**

IF AUTHORITIES HAD known a week in advance about the homemade bombs that were detonated at the 2013 Boston Marathon, all we would remember about the race is the photo of the winner in the next day's newspaper. Predicting where and when someone will use explosives sounds impossible, but bomb making does have telltale signs, and people working on a project called Explosive Material Production Hidden Agile Search and Intelligence System, or EMPHASIS, in Sweden know just where to look for them: the sewers. EMPHASIS is a network of underground electrochemical sensors that can locate explosives by finding the by-products they form in water, such as nitrotoluenes and nitromethane. When high concentrations of bomb ingredients are detected, authorities can use them to begin a search, hopefully locating the makers and stopping their plot before they have a chance to carry it out.



ISIS Is Better at Advertising Than Advertisers

A bold claim by a creative executive at a major advertising agency.

ADVERTISERS AND BRANDS

usually get blamed for screwing up the Internet. We're seen as the ones who brought you banner ads, YouTube commercials, and sponsored content. We're the puppet masters, manipulating your emotions and fueling the engine of consumption. There's some truth to that,

but in the realm of online videos that passionately engage young people and induce them to form communities, we're amateurs compared with ISIS.

The now-notorious execution videos are bad enough. They are shrewdly produced. Slick. The work of experts. But they're not the ones we

should be most uneasy about. The really terrifying ones feature smiling young people, shaky camera work, and an authentic feel. They target our kids.

Thousands of Westerners have joined ISIS over the past several months, something other jihadi organizations haven't been able to do on

SHOULD I STORE MY INFORMATION IN THE CLOUD? "Think of it like using the lockbox at the bank. On one hand, you are putting your valuables in a place where lots of other folks store important things, so it's a prime target. On the other hand, the company operating it is not only super-incentivized to protect your goods, it's also likely to have better expertise at it than anyone else does." – P. W. SINGER, STRATEGIST AND SENIOR FELLOW, NEW AMERICA FOUNDATION



IN THE CLOUD

THE DOX

USED BY: **THEM**

THREATENING PUBLIC figures at their homes is not new, but doxxing, a harassment technique that exposes private information about individuals—sometimes including details such as the name of a day care that a target's child attends—adds a level of anonymity that is attractive to evildoers. For a long time the technique was used mostly by activist hackers against their chosen targets. For example, following the shooting of Michael Brown in Ferguson, Missouri, this past August, members of Anonymous released the name, address, and Social Security number of the St. Louis County chief of police. In October a game designer fled her home when hackers threatened her and her husband following the publication of her address. The same tactic could be used to target government leaders, creating a state of intimidation.



THE SPACE BOMB

USED BY: **THEM**

IF TERRORISTS TOOK OUT our GPS, we'd have worse problems than not being able to find that new restaurant on the edge of town. GPS is also used to guide food-delivery convoys, medical-delivery planes, and weapons. And it wouldn't be too hard to knock it out at the source. Every country is directly beneath space, which is where all the satellites are. Send a nuke up there, and bam, no GPS.

Most countries wouldn't do this; the blast would not only destroy all the low Earth satellites in a wide area, its electromagnetic pulse waves (remember that device that cut the power to Las Vegas in *Ocean's Eleven*?) could fry electronics on the ground, including those of the attacking nation. However, a rogue state with minimal reliance on satellite technology could decide that the collateral damage from eliminating enemy satellites is a price worth paying. Does that sound like anybody we know? North Korea, maybe?

UNBREAKABLE WI-FI

USED BY: **US**

WHEN DISASTER STRIKES, be it an earthquake, industrial accident, or terror attack, cell networks are overwhelmed by the sudden surge in traffic. Many people experienced this on 9/11, when it was near impossible to reach anyone in the New York City area. For first responders, this can add to the confusion of the critical first few hours.

WideBridge, a solution created by Elbit Systems that began testing in September, provides a fail-safe system of protocols built in to existing cell networks that allows firefighters, police, the military, and medical personnel access via cellphones and push-to-talk devices in case of emergency. Responders can talk to each other and can also send information into protected servers, where operators are able to filter and pass along information to coordinate relief efforts. Additional tests are scheduled for early this year.

this scale. ISIS has done it by understanding and deploying modern digital marketing as well as the best digital creators in the world. Michelle Phan and Machinima have nothing on these guys.

Watch the recruiting video featuring Canadian Andre Poulin. He sits in front of a still camera and opens up,

unscripted and vlog style, about his reasons for joining ISIS. He hits all the high points: He's just like you, he's not a social misfit, he understands your life, and he's found belonging. The video uses the same cultural references and production values that its intended audience expects and desires. After the vlog con-

cludes, Poulin runs through a field toward battle accompanied by a narration recounting the glory of his final moments. It's not much different from the voice-overs in thousands of first-person-shooter play-through videos. Poulin's death doesn't look any more final than what happens in Modern Warfare. To the target audi-

ence, Poulin went out in a blaze of glory. Here's a guy who showed *them*, and look at all the attention he's gotten for it.

Forty-five years after the birth of the Internet, it has come to this: The savviest use of digital technology comes from those who would wipe its inventors off the face of the earth.

THE
THREAT
REPORT



THIS MAN WILL SAVE YOU FROM THE EVILS OF THE INTERNET

Last summer a gang of Russian hackers was caught amassing the largest cache of stolen user names and passwords ever discovered—1.2 billion in all. Alex Holden, a Ukrainian immigrant who lives in Milwaukee, found them. And he knows how to do it again.

BY CHRISTOPHER SOLOMON

THE MAN'S DEEP VOICE BOOMS from inside his office, his accent thick and Ukrainian and a little menacing. "I want to show you the black market," he says. He is big—a few inches over 6 feet, round in a sturdy way, goatee trimmed short. He strides around his desk, his feet and belly leading the way. He wears shiny black shoes, black pants, a black pinstriped suit jacket. His name is Alex Holden, although that's not the surname he was born with. The room is in an office park in the grassy Milwaukee suburbs, across the hall from a meat broker that sells beef to school-lunch programs. Hold Security, the name of Holden's firm, is spelled out on the door, slightly crooked, in those reflective letters people stick on their mailboxes. There is no receptionist, almost nothing on the walls. The employee lounge is an unadorned brown sofa from a friend's attic. In one of the few occupied offices, a young analyst named Olga stands in the dark, staring silently at a screen.

Holden settles into a tall black swivel chair, his eyes scanning one of the four monitors lined up on his massive desk. He types, his thick fingers pressing the keys with surprising speed and grace. Images start to appear on his screen. Assault rifles for sale. Counterfeit euros and dollars. Heroin, arranged like a glossy-food-magazine photo of crumbled Parmigiano cheese. Holden types, clicks. Here is Justin Bieber's home address in Calabasas, California. Here's the address, email, and Social Security number for outgoing United States attorney general Eric Holder. All of this in the span of 5 minutes.

Last summer Holden and his firm landed on the front page of newspapers across the country when Hold Security found that Russian hackers had amassed the largest trove of stolen online credentials ever discovered. There were 542 million email addresses and 1.2 billion unique records—email-and-password combinations—in all. Many of the passwords had been decrypted, making them ready for sale on the black market. When I called him a few weeks ago asking to talk with him, he said, “I’m pretty sure after you come visit, you will change your passwords.”

Hold Security employs just 16 people. One victim of last year’s mass hack, JPMorgan Chase, spends \$250 million a year to defend its digital fences, and yet the Russian criminals had been rooting around inside the investment bank’s site for months, hacking, digging, stealing. Holden and his team found them.

“The Internet is a bad place,” he says. “We are playing an interesting game of defense here.” Despite the accent and the heft, Holden himself is actually not menacing at all. He once wanted to be a history teacher and can be windy as a lecturer. He also likes to drop quick, unexpected jokes.

Holden tells me to take a chair. He tilts a big monitor toward me so I can get a better view and gets back to work. The only sounds in the room are the clack of the keyboard and the soft scrape of the mouse on the desk.

As he types, his posture stiffens slightly, and his smile evaporates.

“GOOD MORNING, HUSBAND!” a small Asian waitress chirps to Holden as he walks into Maxfield’s Pancake House, where he’s a regular. Holden, who is divorced, grins big. He only glances at the menu and orders his usual: feta-gyro omelet, no toast, side of cottage cheese. “Atkins,” he says in his *Hunt for Red October* accent.

He talks with enthusiasm about his firm, just two years old and very busy. Being Ukrainian helps, he says—he advertises in Milwaukee’s free Russian-language weekly for people he can train as analysts. This makes Hold Security uniquely suited to focus on the countries of the former Soviet Union, where much financial cybercrime originates. “We’re trying to play where we’re good,” he says, plowing through his omelet.

There are routine computer attacks, like spam and basic kinds of malware, that most security systems will catch or stop. Then there are the kinds of cybercrimes that only people like Alex Holden can find in places that most of us have no idea how to even access. He functions with unusual success in a world of endless shadows, unknown people in unknown places committing sophisticated crimes no one can see, never

BY LAST SPRING, WHEN THE RUSSIAN GANG WAS BAGGING UP TO 100 MILLION STOLEN PASSWORDS AT A TIME, HOLDEN WAS THE FIRST TO KNOW.



Holden says that instead of short-term fixes, he believes in working toward hacker extinction.



even having to leave their homes. And that’s hard. How is Holden able to flourish in a world where corporations and governments are foundering?

When he was a student at the University of Wisconsin–Milwaukee in 1993, Holden talked his way into a programming job by telling a professor that he knew the Visual Basic computer language (he didn’t), then bought a book and taught himself. In the years that followed, most people used the Internet to find information, shop, email friends. Holden, who found the computer and the worlds it contained to be intuitive and compelling, began to explore the tissue that held it together. He never earned his degree, but he did get a job at Robert W. Baird & Co., a global financial-services company in Milwaukee that manages more than \$100 billion in assets. When he was just 27, Holden became its chief information security officer.

In 2013 he was working at a small security company called Cyopsis that split in two, and Holden wound up with his own firm in 4,400 square feet of the suburban office park. Hold’s primary service is “auditing and penetration testing,” he says, which means his team identifies potential weaknesses in clients’ networks that allow thefts while also skulking around online to determine whether their information has been stolen. Sometimes Hold Security tracks the hackers themselves.

Online, Holden is always calculating “when to push, when to let people go”—when to press a hacker for information and when to simply sit back and see where the hacker leads him. There is a psychology to his work, but he is hardly a master manipulator, he says. He might, for example, anonymously approach someone for a small favor—“We just need directions to a forum” or “Point us to documentation on something.” Now he has not only established contact, he also owes the person. He might repay this debt by passing on some useful bit. Maybe the hacker asks him to recom-

mend a new server for spam. "All I have to say is 'I don't know much about spam, but I know you can buy good servers in this legitimate business.' Now we have friendship. We can engage in conversations. Why not? We don't have to talk all about work. I'm going to ask about family. I'm going to say, how do you feel about what's going on in Ukraine, or what's going on with something in politics. It's important not to disagree."

The files Holden keeps on international hackers are stamped CONFIDENTIAL. They are a record of suspects and known criminals. In some of the files are the hackers from October 2013 who Holden and another researcher discovered had broken into Adobe Systems and stolen 3 million customer credit-card records, along with login data and source code for several titles, including Acrobat—a significant theft because of the potential to invite new waves of viruses through popular software.

In more of the files: the criminals who hacked a limousine-software company and leaked credit-card numbers and embarrassing details about 1 million customers, including athletes, politicians, and movie stars. Holden found them in November 2013.

In still others: The criminals from Eastern Europe who broke into and stole a cache of data from the National White Collar Crime Center, the nonprofit that helps law enforcement investigate and prevent cybercrime.

The total number of hacker dossiers, in all, is about 6,500.

• **EVERYONE CAN SEE MOST OF THE INTERNET**, Holden says, but only some people can find the rest, the so-called Deep Web that's not searchable by Google. The Deep Web is hundreds, perhaps thousands, of times larger. Much of it is benign—private company sites and such. "And then there is the black part of the Internet," says Holden—the Dark Web, or Darknet. He enters it on a browser that makes him anonymous and untraceable.

"I'm gonna show you a hacker forum from the inside out," he says, scooting in his chair. He calls up a discussion board, types in two passwords, and gains administrator status, meaning he can move godlike through the forum and read private conversations. A standard board appears, new threads in yellow: "Plastic and Documents." "Passports." "All About Phreaking," or phone hacking.

"They are not giving away kittens or free hugs," he says.

This is the black market?

"It's one of many," Holden says. "We know of maybe 800. We hold seats at many of them."

What happens if, say, your MasterCard was vacuumed up in the breach last Christmas at Neiman Marcus? Holden clicks on another site and up pops a giant picture of a credit card. He logs in. A list appears of Platinum MasterCards for sale, with names, security codes, expiration dates. They are for sale for \$5.20 each. "Shop all you can!" Holden booms.

Once Holden uncovers evidence of theft, he has several options. If instructed by his client, his firm can pay to get information back—like a ransom—though he doesn't like that option because it encourages more theft. Once, when his firm caught hackers siphoning information from a client, Holden seeded the illegal download with bad data, spoiling its value. Sometimes, hackers simply hand him information, rattling out others. "We actually see hackers hack each other," he says. "It's competitive."

While we're talking, a CNN producer calls. Holden apologizes and politely asks me to leave—then puts her on speakerphone loud enough for me to hear. The question is about hackers stealing frequent-flyer points. "Is this something you think is the next frontier of data theft?" she asks.

"We are already seeing this," Holden tells her. "For six to 12 months." He begins a long, detailed explanation. The producer sounds like she's trying hard to keep up.

These forums Holden visits, these passwords—how does he get this

access? He has required, as a ground rule, that I agree not to name any of his 100-plus clients, which he says include brand-name oil companies and Internet firms, nor to reveal his exact sources and methods, which could compromise his work.

"Hackers share these things," he says. He pauses. "We have good, friendly relationships with them."

W

HEN HOLDEN WAS 5, in 1979, his parents tried to emigrate to the United States from Ukraine, then a Soviet republic, and were denied. Once a citizen applied to leave and was blocked, the USSR became a difficult place, but Holden and his family were trapped.

Seven years later the Chernobyl nuclear power plant melted down north of Kiev, leading to mass evacuations. The disaster was the family's ticket out. They fled to Moldova, then reached a temporary location in Italy where they waited to emigrate. Holden, then 14, was put to work cutting grape vines and moving rocks out of farm fields. He missed a year of school.

Eventually the family made it to Wisconsin, where his parents legally changed their surname to better assimilate. (Holden declined to reveal what the old one was, to protect relatives back home from repercussions related to his work.) Holden was an awkward, husky kid, a loner who struggled so much with English that teachers tried to hold him back a grade. After being assigned to eighth grade, he went home and told his parents he wasn't going back. The school bumped him up to ninth. He also felt deeply confused about the United States, which he had always been taught was evil. Suddenly he was told he'd been lied to his whole life. "There was no guidebook *Coming to America for Dummies*," Holden says.

Both his parents had been engineers in Ukraine, and they raised Holden and his brother, Rich, to use their brains. Holden became so skilled at chess, his parents hired a private coach. Their father gave his sons almost weekly engineering puzzles: *Let's figure out why water freezes at this temperature, and how much energy it gives off*. The lessons stuck: Today they're both professional problem solvers—Rich is an assistant professor of informatics and computing at Indiana University–Purdue University, Indianapolis.

As Holden came of age, so did the personal computer. He began to realize its power when a high school biology teacher allowed students to bring one 3 x 5-inch card of notes to the final exam. Holden printed 30 pages of terms and equations on one card, in 2-point font. He graduated six months early.

But Holden has never forgotten how it feels to

Choose Life Grow Young with HGH

From the landmark book *Grow Young with HGH* comes the most powerful, over-the-counter health supplement in the history of man. Human growth hormone was first discovered in 1920 and has long been thought by the medical community to be necessary only to stimulate the body to full adult size and therefore unnecessary past the age of 20. Recent studies, however, have overturned this notion completely, discovering instead that the natural decline of Human Growth Hormone (HGH), from ages 21 to 61 (the average age at which there is only a trace left in the body) and is the main reason why the body ages and fails to regenerate itself to its 25 year-old biological age.

Like a picked flower cut from the source, we gradually wilt physically and mentally and become vulnerable to a host of degenerative diseases, that we simply weren't susceptible to in our early adult years.

Modern medical science now regards aging as a disease that is treatable and preventable and that "aging", the disease, is actually a compilation of various diseases and pathologies, from everything, like a rise in blood glucose and pressure to diabetes, skin wrinkling and so on. All of these aging symptoms can be stopped and rolled back by maintaining Growth Hormone levels in

the blood at the same levels HGH existed in the blood when we were 25 years old.

There is a receptor site in almost every cell in the human body for HGH, so its regenerative and healing effects are very comprehensive.

Growth Hormone first synthesized in 1985 under the Reagan Orphan drug act, to treat dwarfism, was quickly recognized to stop aging in its tracks and reverse it to a remarkable degree. Since then, only the lucky and the rich have had access to it at the cost of \$10,000 US per year.

The next big breakthrough was to come in 1997 when a group of doctors and scientists, developed an all-natural source product which would cause your own natural HGH to be released again and do all the remarkable things it did for you in your 20's. Now available to every adult for about the price of a coffee and donut a day.



GHR now available in America, just in time for the aging Baby Boomers and everyone else from age 30 to 90 who doesn't want to age rapidly but would rather stay young, beautiful and healthy all of the time.

The new HGH releasers are winning converts from the synthetic HGH users as well, since GHR is just as effective, is oral instead of self-injectable and is very affordable.

GHR is a natural releaser, has no known side effects, unlike the synthetic version and has no known drug interactions. Progressive doctors admit that this is the direction medicine is seeking to go, to get the body to heal itself instead of employing drugs. GHR is truly a revolutionary paradigm shift in medicine and, like any modern leap frog advance, many others will be left in the dust holding their limited, or useless drugs and remedies.

It is now thought that HGH is so comprehensive in its healing and regenerative powers that it is today, where the computer industry was twenty years ago, that it will displace so many prescription and non-prescription drugs and health remedies that it is staggering to think of.

The president of BIE Health Products stated in a recent interview, I've been waiting for these products since the 70's. We knew they would come, if only we could stay healthy and live long enough to see them! If you want to stay on top of your game, physically and mentally as you age, this product is a boon, especially for the highly skilled professionals who have made large investments in their education, and experience. Also with the failure of Congress to honor our seniors with pharmaceutical coverage policy, it's more important than ever to take pro-active steps to safeguard your health. Continued use of GHR will make a radical difference in your health, HGH is particularly helpful to the elderly who, given a choice, would rather stay independent in their own home, strong, healthy and alert enough to manage their own affairs, exercise and stay involved in their communities. Frank, age 85, walks two miles a day, plays golf, belongs to a dance club for seniors, had a girl friend again and doesn't need Viagra, passed his drivers test and is hardly ever home when we call - GHR delivers.

HGH is known to relieve symptoms of Asthma, Angina, Chronic Fatigue, Constipation, Lower back pain and Sciatica, Cataracts and Macular Degeneration, Menopause, Fibromyalgia, Regular and Diabetic Neuropathy, Hepatitis, helps Kidney Dialysis and Heart and Stroke recovery.

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PROJECT

The Handsome Log Rack

How to transform a maple tree and some steel into a functional piece of art.

BY ROY BERENDSOHN AND MIKE CUNNINGHAM



M

AN, IT'S CHILLY. WHAT KIND OF WEATHER WE GOT OUT HERE, A BLIZZARD?

Why don't you reach into that log rack, pull out a split, and start a fire for us? Why, yes, thank you, it is a nice log rack. We built it out of a poorly located maple tree and a pile of raw steel. Added a little wood stain but left the screws and the metal unfinished so it would look utilitarian. Not so utilitarian that it's out of place in an elegant room, but, you know, a little rough. Brawny. It's a piece of furniture that says, I could navigate a toolshed in the dark but couldn't find my way around a Bed Bath & Beyond with an iPhone, a compass, and a map. This, it should be noted, is an impressive feat for furniture.

Materials

PART	QTY.	DESCRIPTION	DIMENSIONS
A	2	Steel upright	1/4" x 1 1/2" x 44"
B	4	Steel cross support	1/4" x 1 1/2" x 16"
C	2	Hardwood log	6" dia. x 22 1/2"
D	8	Button-head machine screw	5/16"-24 x 3/4"
E	4	Spax lag screw	1/4" x 3" T30
	1	Pint pre-stain wood conditioner	
	1	Pint oil wood stain	

EQUIPMENT

- Bar clamp
- Car wheel rim
- Chainsaw
- Chisel
- Corded drill
- Drawknife or putty knife
- Drill bit
- Hacksaw
- Right-angle grinder and abrasives
- Screwdriver bits
- Tap and tap handle
- Tap lubricant
- Disposable paintbrush
- Sandpaper or abrasive discs

STEP 1

Bend the Uprights

FIRST, FIND A FRIEND. To make the uprights that will hold your firewood, you'll need to bend two pieces of 1 1/2-inch x 4-foot flat steel, which you can buy at home stores or at metalsdepot.com, into U shapes, and you can't do it alone. Using a bar clamp, arrange the first piece of steel next to an old tire rim so that it looks like a P (Fig. 1). Now clamp the rim in a big bench vise. Have your friend yank the long end of the steel around the curve. As it starts to come around, grab the bar and pull while your friend pushes. Once the steel is roughly U-shaped, remove any unevenness: Clamp the U in a bench vise and sight down the side to check for any vertical twisting. Use your hands to bend that out. Next, cut both ends of the U so that they're even (Fig. 2). Use a hacksaw or a circular saw with a metal-cutting blade. Now repeat this whole process for the other U. Next, cut the four cross supports to length and bore 5/16-inch bolt holes into both ends of each. Use those holes to mark the position of the holes in the upright legs of the U. If you have a letter-size drill-bit set, use the I-size bit; otherwise, use a 17/64 fractional-size drill. Add threads to these holes with a 5/16-inch-24 tap and a large tap-wrench handle (Fig. 3).

TIP

Don't skip on the lubricant when adding threads to the holes for the machine screws. Lack of lubricant can result in a stuck or broken tap.

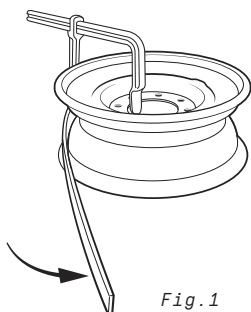


Fig. 1
Bending the steel

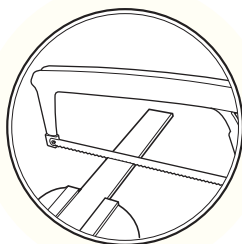


Fig. 2
Evening out the U

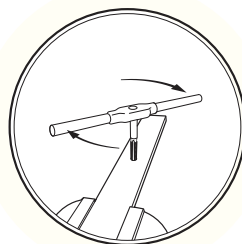


Fig. 3
Tapping screw holes

THE PROJECT PLAYLIST

Because you are not going to build this log rack in silence.



Sturgill Simpson

"Life of Sin"

A reincarnation of Johnny Cash—with a drawl that makes everything he sings sound like, "Whaddaya say, man, another beer break?"

Dinosaur Jr.

"Start Choppin'"

A cult classic that's like an alarm you set for noon on Sunday, just to make sure you don't sleep all day. Easy but urgent.

The Neighbourhood

"Sweater Weather"

A young-couple-against-the-world anthem, in which Jesse Rutherford lets his girl warm her cold hands in the sleeves of his sweater.

The Walkmen, "Heaven"

Lush, woodsy, and nostalgia-inducing, like a barn party with a really excellent bonfire.

Pearl Jam, "Getaway"

A driving ode to getting things done your own way.

The Rolling Stones

"Beast of Burden"

One of the best songs to do just about anything to.

The Black Keys

"Gold on the Ceiling"

Organ riffs, snarly guitars, and a beat like a train engine should get you through any late project slump.

Tompall Glaser

"Put Another Log on the Fire"
A tongue-in-cheek account of what might happen if you ask your wife to do your chores for you.

Log Rack

STEP 2

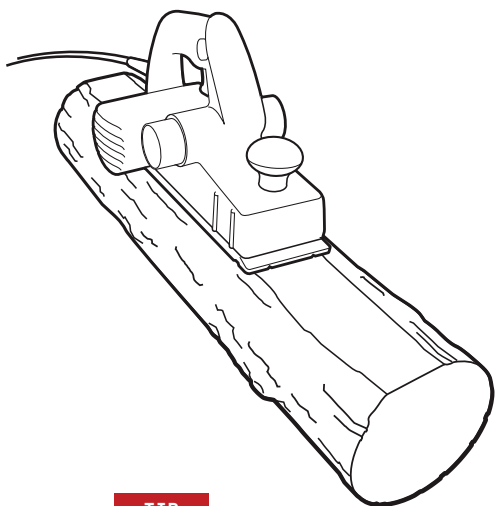
Create the Log Base

GENTLY ASSEMBLE the rack, lining up the parts with a carpenter's rafter square. Don't tighten the machine screws yet. You'll need to take everything apart to deburr it before final assembly.

Debark two logs with a putty knife if the wood is seasoned, or a drawknife if the logs are green. Use a power plane to flatten the bottom of the logs (Fig. 4). You'll take off about $\frac{1}{2}$ inch of wood. Sand the logs with 60-, 80-, and then 100-grit paper.

Mark the place where the U-shaped uprights will sit on the logs, and notch the logs with a chainsaw or a large chisel; then smooth out the notches with a chisel or a wood rasp, if you own one. Where the rack meets the logs, mark the position for one $\frac{3}{16}$ -inch hole in each U-shaped upright for a $\frac{1}{4}$ x 3-inch Spax lag screw. Drill each hole. Test-fit the rack to the notched logs and adjust the notches if needed. When everything fits, disassemble the rack.

Fig. 4
Planing the logs



TIP

We used a power plane to give our logs a flat base, but if the logs are smooth and of a consistent diameter, you can also feed them through a small benchtop planer.

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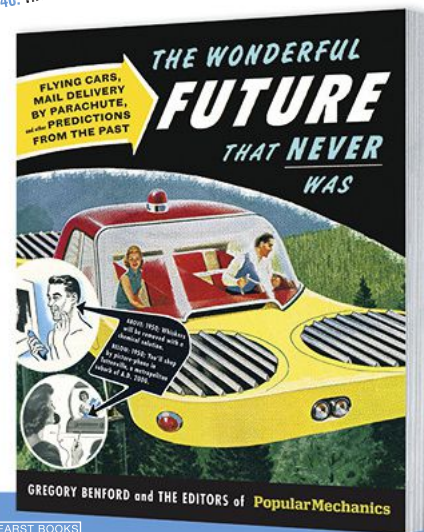
BACK TO THE
FUTURE

1940: The torpedo-like rail car of tomorrow ▶

OVER THE DECADES, scientists have peered into their crystal balls, envisioned the world to come...and shared their predictions with readers of *Popular Mechanics*.

What did they see? Flying ambulances. Space suits made from paper. Utopian cities with elevated sidewalks and sunken streets. Even the cure for the common cold.

In our book—a collection of these speculations with original text by Nebula winner and NASA advisor Gregory Benford—the bizarre, wildly imaginative, and (occasionally) eerily accurate *Wonderful Future That Never Was* comes to life.



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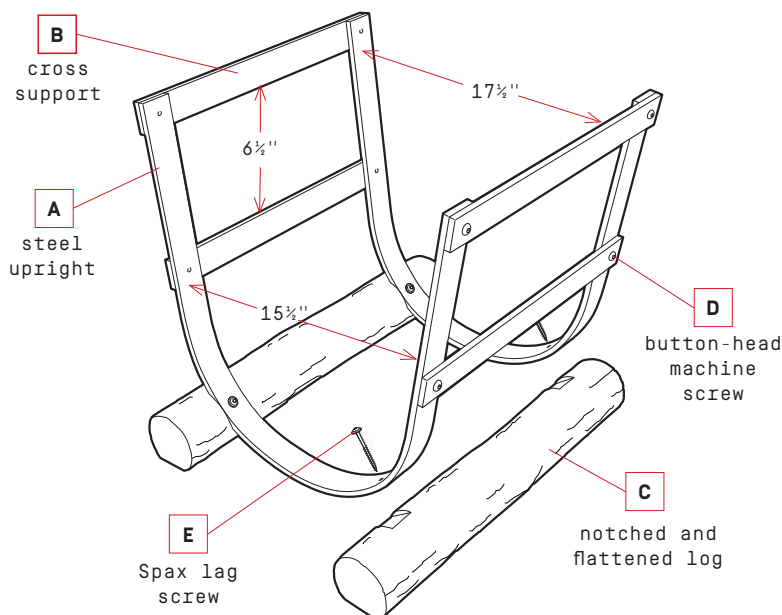
STEP 3

Finish and Assemble the Holder

A

APPLY A COAT of Rust-Oleum pre-stain wood conditioner to the logs. When that's dry, brush on a coat of wood stain. We used Rust-Oleum's Kona shade. Grind the metal parts smooth using sanding discs and an angle grinder. Start with 24-grit and work through 36-, 40-, 60-, and 80-grit. If you want a polished look, do the final sanding with 100-grit.

Finally, bolt the metal rack together and firmly tighten the machine screws. Grind the screws flush on the inside of the rack with a 24-grit disc and smooth off any rough areas. Use the lag screws to connect the rack to the finished logs. There you have it—a new log rack. Now all you need to do is fill it. Maybe the kids could help with that.



THE WOOD REPORT

Clean-burning, good-smelling woods to put in your new log rack, according to a study by the Utah State University forestry program.



Apple



White Oak



Ash



Honey Locust



Black Walnut



Maple

CREDITS

Credits

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How a Chicago Doctor *Shook Up* the Hearing Aid Industry with his *Newest* Invention

New nearly invisible digital hearing aid breaks price barrier in affordability

Reported by J. Page

Chicago: Board-certified physician Dr. S. Cherukuri has done it once again with his newest invention of a medical grade **ALL DIGITAL affordable hearing aid**.

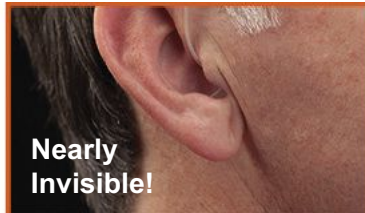
This new digital hearing aid is packed with all the features of \$3,000 competitors at a mere fraction of the cost. **Now, most people with hearing loss are able to enjoy crystal - clear, natural sound—in a crowd, on the phone, in the wind —without suffering through “whistling” and annoying background noise.**

New Digital Hearing Aid Outperforms Expensive Competitors

This sleek, lightweight, fully programmed hearing aid is the outgrowth of the digital revolution that is changing our world. While demand for “all things digital” caused most prices to plunge (consider DVD players and computers, which originally sold for thousands of dollars and today can be purchased for less), the cost of a digital medical hearing aid remained out of reach.

Dr. Cherukuri knew that many of his patients would benefit but couldn't afford the expense of these new digital hearing aids. Generally they are *not* covered by Medicare or most private health insurance.

The doctor evaluated all the high priced digital hearing aids on the market, broke them down to their base components, and then created his own affordable version—called the MDHearingAid® *AIR* for its virtually invisible, lightweight appearance.



Nearly Invisible!

SAME FEATURES AS EXPENSIVE HEARING AID COMPETITORS

- ✓ Mini Behind-The-Ear hearing aid with thin tubing for a nearly invisible profile
- ✓ Advanced noise reduction to make speech clearer
- ✓ Feedback Cancellation eliminates whistling
- ✓ Wide dynamic range compression makes soft sounds audible and loud sounds comfortable
- ✓ Telecoil setting for use with compatible phones, and looped environments like churches
- ✓ 3 programs and volume dial to accommodate most common types of hearing loss even in challenging listening environments

Affordable Digital Technology

Using advanced digital technology, the MDHearingAid® *AIR* automatically adjusts to your listening environment—prioritizing speech and de-emphasizing background noise. Experience all of the sounds you've been missing at a price you can afford.

The MDHearingAid® *AIR* is FDA registered. This doctor designed and approved hearing aid comes with a full year's supply of long-life batteries. It delivers crisp, clear sound all day long and the soft flexible ear buds are so comfortable you won't realize you're wearing them.

FDA Guidance and Consumer Education

The FDA states that only FDA-registered hearing aids, such as the MDHearingAid AIR should be used to help people with hearing loss. Imitation “Personal Sound Amplifiers (PSAPs)” are not a substitute for hearing aids and can, in fact, lead to more damage in your hearing.

Try It Yourself At Home With Our 45 Day Risk-Free Trial

Of course, hearing is believing and we invite you to try it for yourself with our RISK-FREE 45-day home trial. If you are not completely satisfied, simply return it within that time period for a full refund of your purchase price.

MDHearingAid® *AIR*

Can a hearing aid delay or prevent dementia?

A study by Johns Hopkins and National Institute on Aging researchers suggests older individuals with hearing loss are significantly more likely to develop dementia over time than those who retain their hearing. They suggest that an intervention—such as a hearing aid—could delay or prevent dementia by improving hearing!

“Satisfied Buyers Agree AIR Is Best Digital Value!”

“I am hearing things I didn't know I was missing. Really amazing. I'm wearing them all the time” —Linda Irving, Indiana

“Almost work too well. I am a teacher and hearing much better now” —Lillian Barden, California

“I have used many expensive hearing aids, some over \$5,000. The AIRS have greatly improved my enjoyment of life” —Som Y., Michigan

“I would definitely recommend them to my patients with hearing loss” —Amy S., Audiologist, Munster, Indiana



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be a perennial outsider. The frustration and lack of opportunity—it was palpable in the men in south central Russia with whom he connected about 18 months ago. There were about a dozen low-level spammers, all in their 20s, led by a man they called Mr. Grey. Holden chatted up the gang anonymously. At first Mr. Grey's group was only after old lists of emails they could get cheap. But eventually the group became more ambitious, acquiring logins and passwords to access social-media sites, a more effective way to spam because messages look like products endorsed by friends.

By last spring the gang, which Hold Security dubbed CyberVor (*vor* is Russian for "thief"), was bagging up to 100 million credentials at a time, including data fresher than the old email lists. Holden learned that CyberVor was controlling a botnet—an army of computers run by malware, or malicious software. When an infected user visits a website, hackers use the botnet to see if the site is vulnerable in a way that would allow them to steal data from it. When CyberVor ended up with the largest data theft ever, Holden was the first security expert to know.

HOLDEN WANTS A STEAK. After he eats a thick Midwestern slab at a downtown Milwaukee steakhouse, he takes me up to a penthouse bar. He'd mentioned the great views—across the city to Lake Michigan and beyond—but clouds blot out the skyline. He leans back in a tall, upholstered chair, and after a sip of a rum and Diet Coke he says, "Let's do an experiment." When he visited southern Italy, he noticed the manhole covers were square. He asks me, why would they make square manholes?

I sit for some time in uncomfortable silence. Finally, I answer: Old Italy equals cobble streets. A round manhole wouldn't fit among blocks, but a square one would.

He seems a little surprised, but the correct answer is not what interests him. Look how you're folded up in your chair, he says. You're not relaxed. On the other hand, he points out, your head is tilted down and to the left—you're thinking, hard. When he interviews people for jobs, he's interested not just

in the answers but in how they react to stress. As he puts it: "We have 'oh my God' moments quite often."

For much of his boyhood, Alex Holden was unsure of his place in the world, his family moving from country to country as if fleeing, the boy searching for an acceptance he rarely felt. When his aloneness led him to something he was good at, that made him feel good, he used his knowledge to do good in return. Now he looks for people who feel the way he did about their place in the world, but who have succumbed to the alienation.

The morning after the bar, Holden shows me one of the confidential dossiers. Here is the criminal's online alias, home address, marital status. Here are pictures—of the hacker dancing, at the beach, with friends. One of them, a young Eastern European, was looking for programming work in 2013. After striking out, he helped design the malware that shredded Target's network that Christmas season, stealing personal data from as many as 70 million customers. Thieves used some of the stolen credit-card numbers to go on spending sprees; banks imposed tight debit-card restrictions, further infuriating travelers and holiday shoppers and inflaming fears about the safety of online information and identities. But Holden echoes what he said during the experiment in the bar, about not getting emotional. "If you're angry about this," he says, "you lose your good judgment."

About 10 years ago Holden was auditing a large financial institution's network. He found a gaping vulnerability. At one moment, "I can see I can access \$272 million as an electronic funds transfer," he says. He was alone, just him and a whirling computer. "At that point, your eyes kind of glaze over. And you think about it. This is bigger than most lotteries." For 10 long seconds he sat staring at the monitor. *Wow, I don't even know what \$272 million would look like.*

Then he blinked, shook off the daydream, documented the bug, and got back to work. ■

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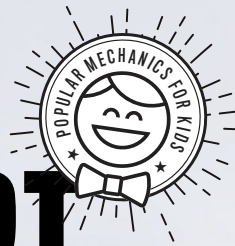


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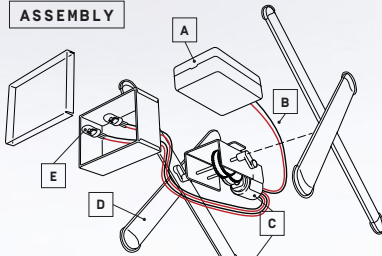


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TIME: 2 hours (or less)			
AGES: 7+			

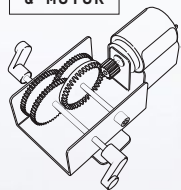
T HIS LITTLE MACHINE is loaded with lessons about engineering and mobility. The gearbox teaches kids how gear ratios affect speed. And when it walks, the robot's feet can slip unless you add a dab of glue to them. That's a great introduction to problem solving: increasing friction to create traction and enable faster movement.

The pipe cleaners are just pipe cleaners. Have fun!

ASSEMBLY



GEARBOX & MOTOR



Plastic battery package becomes the robot's head!



MATERIALS AND TOOLS

(all available at hardware and craft stores, except where noted)

PART	QTY.	DESCRIPTION
A	1	Two-battery AA or AAA case, with switch
B	2	5-in. pc. each red and black electrical wire
C	1	Elenco 2-in-1 Gearbox Strength: 1:288; speed: 1:60 (elenco.com)
D	4	Ice-pop stick
E	2	3-volt, 10-mm LED (leading-leds.com)
		Lightweight plastic box, open in back (we used the batteries' packaging)
		• wire cutter/ stripper
		• duct tape
		• scissors
		• hot-glue gun
		• electrical tape
		• glue sticks
		• craft supplies

INSTRUCTIONS

● parent only ● parent and kid ● kid only

STEP-BY-STEP

1. Assemble gearbox using the manufacturer's instructions.
2. Strip ½ inch of insulation from the end of each wire.
3. Twist a red wire onto the long leg of one LED, and a black wire onto the short leg. Repeat with second LED.
4. Attach the battery case's red and black wires to the motor terminals. The red wire goes to the terminal near the + sign.
5. Twist the red LED wires around the red wire attached to the motor, and cover the connection point with electrical tape. Repeat with black wires.
6. To add rigidity to the wires connecting the LEDs to the motor, wrap each pair of wires tightly with electrical tape.
7. Hot-glue the battery case onto the back of the gearbox.
8. Hot-glue the ice-pop sticks into two Xs, and then glue one X to each end of the gearbox axle (we reinforced the connections with red duct tape).
9. Hot-glue both LED wires to the curved underbelly of the motor mount. Hot-glue the LED bulbs to the inner sides of the plastic box.
10. Decorate with craft supplies to make the robot look awesome.



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• Use as directed for occasional sleeplessness. Read each label.
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